United States
Department of
Agriculture

Economics and
Statistics
Service

Agricultural
Economic Report
Number 472

Economies of Size in U.S. Field Crop Farming

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Economies of Size in U.S. Field Crop Farming, by Thomas A. Miller, Gordon E. Rodewald, and Robert G. McElroy. National Economics Division, Economics and Statistics Service, U.S. Department of Agriculture. Agricultural Economic Report No. 472

Abstract

Economies of size refers to the relative cost efficiency associated with different firm sizes. As farm size increases in most field crop regions, per-unit costs decline at first and then are relatively constant. Medium-size commercial farms ($41,000 to $76,000 gross income) achieve most available technical cost efficiencies. Society would likely benefit little in terms of lower real food costs from further increase in the size of these farms. Apparently economies of size are not a major factor in farm enlargement; farmers expand their farms to increase income rather than to reduce per-unit costs.

Keywords: Economies of size, cost efficiency, wheat, feed grain, cotton, farm structure, farm growth, policy.

Washington, D.C. 20250 **July 1981**

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Summary

Increasing farm size does not necessarily increase farm efficiency or productivity. In fact, small farms in many field crop regions are nearly as technically efficient as large farms. And farmers of all sizes of operations tend to enlarge their farms in search of higher income rather than to increase per-unit cost efficiencies. Technical economies of size refers to the physical relationship between inputs and outputs and assumes all farm sizes receive and pay identical prices.

Farms producing wheat, feed grains, and cotton in seven field crop regions of the United States were studied to determine the importance of technical economies of size in the farm sector and to examine how such cost economies may change farm structure. Cost efficiency was estimated on four hypothetical farm sizes in each region from data obtained during the 1978 USDA cost of production survey. Regional differences were found: cost efficiencies between the smallest and largest farms ranged from $0.16 in the Southern Plains to $0.05 in the Mississippi Delta. But all study regions showed the same general economies-of-size relationships.

As farm size increases, per-unit costs decline at first and then are relatively constant over a wide range of sizes. The average of the gross incomes for the most efficient farm size in each region was $133,000 with cash costs of $0.61 per dollar of gross income. In comparison, small farms with gross incomes of $18,000 had costs of $0.71, and medium-size farms averaging $59,000 gross income had cash costs of $0.63 per dollar of gross income. Cash costs (including machinery replacement costs) declined about $0.10 per dollar of gross income over the $115,000 range of gross income studied.

Net farm income on small farms is limited by low-volume production, not by reduced cost efficiencies. The income from such farms is often inadequate to support a family. However, returns to land and operator inputs range from $0.14 to $0.47 per dollar of income on the smallest farms. Since these farms are usually part-time units, such cost efficiencies appear sufficient to allow them to continue meeting cash expenses and to return a small but positive net farm income. Such farms can be viable in regions where family income can be supplemented by off-farm employment.

If economies of size are relatively unimportant in field crop regions, why do farms continue to grow? This study best supports the explanation that small farms generate low incomes, and these low incomes cause such farms to exit, become part-time units, or expand to increase income whether or not economies of size exist. Farmers tend to enlarge their operations in search of higher incomes, rather than to increase per-unit cost efficiency.

Since medium-size commercial farms with gross incomes from $41,000 to $76,000 achieve most technical cost efficiencies, society benefits little in terms of lower real food costs from further increases in farm size. Actually, many commercial farms now exceed the size necessary to achieve all available cost efficiencies. With current field crop production technology, further growth in medium-size and larger farms will not likely improve overall food production efficiency.

When economies of size are minor, society can consider many issues related to farm size separate from questions of overall economic efficiency and food costs. For example, the 160-acre limit of the Reclamation Act of 1902 could increase food prices by increasing longrun production costs. However, a much more probable impact would be to lower rents, depress land prices, and decrease the wealth of landowners, without affecting food prices. Based on the relatively minor economies of size found in this study, it is unlikely that moderate limits of farm size would have either impact in major field crop regions.

Of course, those farmers affected by size limit policies suffer a relative income loss, even without economies of size. The potential benefits of such policies must be measured against these income losses as well as against the possible adverse impacts on wealth and efficiency.

Economies of Size in U.S. Field Crop Farming

Thomas A. Miller, Gordon E. Rodewald, and Robert G. McElroy*

Introduction

Increasing farm size does not necessarily increase farm efficiency or productivity. In fact, small farms in many field crop regions are nearly as efficient as large farms. And farmers of all sizes of operations tend to enlarge their farms in search of higher income, rather than to increase per-unit cost efficiencies. This report focuses on technical economies of size to determine their importance in the farm sector, and to examine their impact on farm structure.

Problems and Issues

Economies of size deal with the efficiency (cost economies) associated with different firm sizes. Information on economies of size is useful to farmers in their decisionmaking. It also helps farmers, consumers, and policymakers understand how food production efficiency is affected by structural change in farming.

Farm Management Questions. Farmers are interested in economies of size for making long term plans in regard to the size of their operation and the use of land and machinery. Such information tells them about the relative efficiency of different farm sizes and indicates how changes in farm size may affect efficiency.

Beginning farmers need to know how resource return rates on small farms compare with returns on the most efficient farms. Expanding farmers need to know how large a farm must be in order to achieve most available economies of size and about any possible diseconomies that may be associated with large-scale operations. Both beginning farmers and expanding farmers are interested in expected family incomes associated with different farm sizes. Studies of economies of size can provide much of this information.

Food Costs and Efficient Farm Sizes. Former Secretary of Agriculture Bob Bergland instituted a national dialogue on farm structure *(33, 34)*.[1] This discussion brought out other questions about economies of size. One involves the efficiency of resource allocation in the farm production sector. Inefficient resource allocation implies that total food production costs are higher than necessary. Society thus has a definite interest in assuring that agriculture is organized so that production takes place on efficient farms that achieve most available economies of size.

A number of developed and developing countries have policies to increase the size of farms to a more efficient scale of operation. In the United States the problem is somewhat different since ever-increasing farm size and concentration in the control of agriculture's resources have led to concern that many farms are growing far beyond the size required for efficient production. Declines in the number of family farms and the impact of dwindling populations on rural communities are readily apparent in many regions and represent possible social and political costs associated with increasing farm size. These concerns have raised questions about policies that would limit or reduce farm size or slow the rate of farm consolidation (*31*, pp. 63-65). A recent USDA study provides additional background on the problem *(33)*.

This report will use terms such as "farm-size policy" and "size-limit policy" in a general sense referring to any public policies to affect farm size. Such policies could conceivably involve a wide range of components. These include changes in income tax or inheritance laws, a refocus of public credit programs, land use controls, and changes in the distribution and size of commodity program benefits *(33)*. The proposed "160-acre limitation" for Bureau of Reclamation project farms is a specific example—it would directly limit farm size on certain Bureau of Reclamation projects *(13, 17, 25)*.

The potential danger is that if economies of size are significant in agriculture—and if farms are currently operating at an efficient size—such policies could reduce the overall efficiency of food production. Alternatively, in the absence of size economies, there is no efficiency loss to society from having a size distribution dominated by small farms or large farms if the per-unit cost is the same. In such a "constant cost industry," several alternative farm

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[1]Italicized numbers in parentheses refer to items in the References section.

size structures may be possible without affecting overall production efficiency. Then society could choose among these structures based on their social or aesthetic merits without worry about increasing total food production costs.

Structural Change and Economies of Size. Another economies-of-size question involves future trends in the size distribution of farms. A popular belief is that economies of size are a moving force behind structural change in agriculture (*13*, p. 925). The relationship between farm size and efficiency may change over time as the availability of new technology allows additional efficiencies in large-scale resource use. As the size of operation required to obtain maximum efficiency increases, farms are forced to grow to remain competitive. This process implies that economies of size in farming must be monitored to anticipate future structural change and that policies to change the size distribution of farms should focus on the technical factors responsible for the change.

A contrasting belief is that many other factors provide the incentive for farm expansion: inflation, the expectation of future capital gains from land price increases, tax laws, and farmers' search for larger incomes. Proponents of this view argue that these factors provide the driving forces behind the growth in average farm size; economies of size may allow this growth to take place but are not the central cause of it. In this case, attention should be turned toward these other economic factors to understand and/or influence future structural change in farming. If economies of size are not the primary cause of structural change in agriculture, then policies to influence structure should be concerned with these nontechnical growth incentives.

Objectives of this Report

Farmers are interested in economies-of-size relationships in making longrun decisions regarding the size of their business. Economies of size in production agriculture also have apparent implications for policymakers interested in farm growth, the process of structural change, and understanding the impact of farm programs modifying structural change. Debate on 1981 farm legislation may consider both of these issues while extending or developing specific commodity programs.

Since recent comprehensive studies of economies of size are not available for wheat, feed grains, and cotton, these crops are the focus of the economies-of-size measurements in this report. It provides empirical estimates of economies of size and analytically reviews theory and research relating to the policy issues. This report will address the following objectives:

- Determine the importance of technical economies of size in seven major U.S. field crop producing regions;
- Investigate the role these economies of size play in the process of structural change—particularly for increasing farm size; and
- Given the nature and extent of these technical economies of size, explore the possible impacts of farm size-limit policies, including the potential of such policies to increase food prices or decrease resource returns.

Theoretical Considerations

The framework for economies-of-size research comes from the economic theory of the firm under perfect competition. This theory rests upon a rigorous set of assumptions to describe the relationship between size and efficiency. While all of the conditions of perfect competition are not present in production agriculture, they are approximated well enough to provide the basis for making empirical estimates of economies of size. A review of the relationship between economies of size and the theory of the firm under perfect competition is helpful to understand the basis for estimating economies of size and the strengths and limitations of these estimates (*5, 6, 11*).

Resource Fixity, Length of Run, and Economies of Size

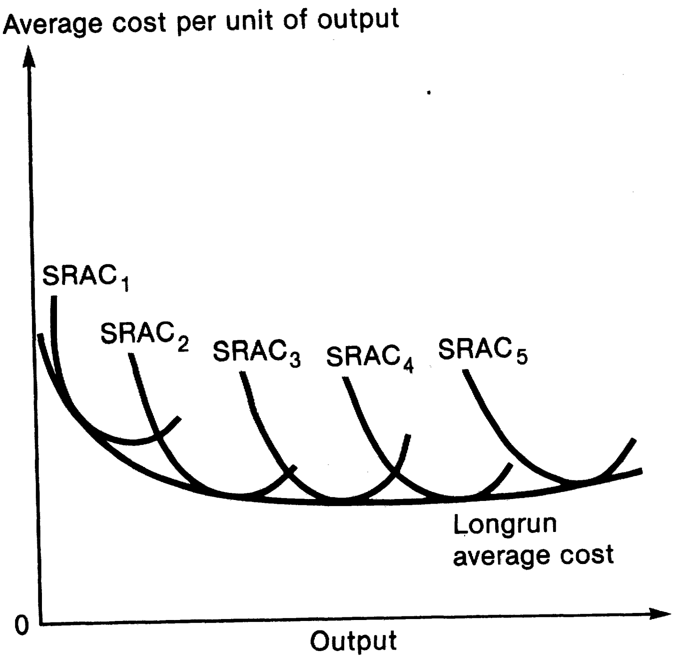
Economies of size are generally described in terms of short run and long run. The shortrun period is long enough to permit changes in output which are technologically possible without altering the farm size. The longrun period permits all types of adjustment, both in farm size and degree of resource utilization. Thus, shortrun cost economies result from the more efficient utilization of a fixed size of farm. Longrun cost economies, or economies of size, result from the efficiencies obtained by changing farm size.

This concept is illustrated graphically in figure 1, which shows the hypothetical relationship between shortrun and longrun average cost curves. The shortrun average cost (SRAC) relationships assume one or more resources are fixed in the short run. As the output of the farm increases by applying more variable inputs to these fixed resources, average costs per unit of output decline rapidly at first because the associated fixed costs are spread over more units. At some point, average costs increase as a result of diminishing returns to the variable input (fig. 1, $SRAC_1$). A separate SRAC curve applies to each level of fixed resources—each different size of farm. For each farm size, the greatest efficiency in the use of all production resources is achieved at the lowest point on the SRAC curve representing that size of farm. This output level represents the most efficient utilization of that bundle of fixed resources.

In farming, operator labor and management, machinery, or land resources may be fixed in the short run. For example, each SRAC curve may represent the behavior of costs as output is increased by using higher levels of variable inputs on a farm with a fixed land acreage.

Figure 1.

Hypothetical Shortrun and Longrun Average Cost Curves



In the long run, all resources are by definition variable, and farm size is assumed to freely adjust to the most efficient mix of resources. In figure 1, longrun average costs (LRAC) are represented by estimating a series of SRAC relationships for different sizes of farms and drawing a curve tangent to these shortrun curves. This longrun average cost "envelope" represents the most efficient method of producing each level of output, considering all possible combinations of variable and fixed resources.

The fixity of specific resources in the short run depends on their physical longevity, the relevant planning horizon, discontinuities, and prevailing farm practices. For economies-of-size studies, however, the choice of a particular resource as fixed in the short run is an arbitrary decision and has little effect on the final results. Each arbitrary choice of a fixed resource may result in a SRAC curve with a slightly different shape because the remaining factors combine with it at different rates. However, the low point of the SRAC curve is not changed since it represents the most efficient combination of all other variable factors with the fixed resource. The resulting LRAC envelope curve is not affected by the choice of a fixed resource (*11*, p. 4).[2]

The LRAC curve thus represents the lowest average cost per unit of output that can be achieved by farms of different sizes under specified price and technological relationships. The decreasing average costs are largely achieved through improved technical relationships between resources that have some degree of discontinuity. Larger farms are also able to utilize larger, usually more efficient machines in their production process. The curve suggests that diseconomies may result if expansion is carried too far. Such eventual increases in average costs are difficult to document due to lack of essential data, but are often the inevitable result of the increasing difficulties of management on larger units. The curves represented in figure 1 are hypothetical relationships. The actual size-efficiency relationship for a particular industry and location must be determined through empirical investigation.

Working Definitions

While figure 1 depicts the theoretical framework behind economies-of-size studies, the actual estima-

[2]Strictly, only the low point (or horizontal segment) of the LRAC curve is unaffected. Since choice of the fixed resource can affect the shape of the SRAC curves (but not their low point), this choice can consequently affect the downward or upward sloping segments of the LRAC envelope curve. Generally, this effect is ignored in estimating economies of size.

tion of such relationships for a particular industry requires additional definitions or procedures as a practical necessity. Most of these definitions and procedures are necessary because agriculture is not a perfectly competitive industry in the strict sense.

Potential Versus Actual Efficiency. For a given set of prices, resource qualities, and technology, the LRAC envelope represents the most efficient possible utilization of resources—and is referred to as the efficiency frontier. It is theoretically impossible to achieve lower costs at any output level. It is quite possible, however, to produce any given level of output at a higher cost. One example would be operating at a point on the SRAC curve other than the point of tangency with the LRAC, such as not fully utilizing a major equipment item or other fixed resource. In addition, farmers may not use the most efficient technology available for their size of business, they may differ in managerial abilities, or they may make planning or husbandry errors. As a result, the actual average unit costs of real farms may be considerably above the efficiency frontier. Economies of size refers to potential efficiency, in contrast to the actual or realized efficiency obtained on existing farms.

Economies of Size Versus Economies of Scale. This report uses the expression economies of size rather than economies of scale. The two expressions have been used almost interchangeably by some economists. In technical terms, economies of scale requires constant resource proportions and describes the behavior of average costs for various output levels when all resources are varied in exactly the same proportion. Since such constant proportions are an impossibility in the real world, empirical work generally relaxes this condition and allows changes in resource and product proportions to maintain efficiency as output is expanded. The term economies of size is used to denote this practice and refers to the general relationship between average per-unit costs and size of operation with variable resource proportions.

Technical Versus Market Economies of Size. Economists also distinguish between technical efficiency and economic efficiency. Technical efficiency relates to the physical relationships between inputs and outputs. Economic efficiency reflects these physical relationships as well as the prices paid for inputs and the prices received for outputs. Technical economies of size include both of these efficiencies, but with all sizes of farms facing identical input and product prices. Market economies of size result strictly from differences in prices paid and prices received on different sizes of farms; for example, volume discounts on fertilizer purchases. The research in this report focuses on technical economies of size. Market economies are not analyzed, so all of the cost economies reported are due to technical factors.

Classification of Costs

In order to estimate the shortrun average costs of a farm, costs must be classified as variable and fixed, corresponding to the variable and fixed resources. Table 1 shows a possible classification of resources and costs for this purpose.

Cash Production Costs. The production inputs and their associated cash production expenses in table 1 are generally considered variable in the short run.

Table 1—Classification of resources and costs for economies-of-size studies

Resource or input	Cost
Hired labor Seed Fertilizer and chemicals Custom operations Machinery repair and maintenance Machinery fuel and lubrication Interest on operating costs	Cash production costs, plus
Machinery replacement costs Taxes on machinery Machinery insurance	Cash machinery costs, plus
Real estate taxes General farm overhead	Other cash costs
	Equals total cash costs
Owned land Operator and family labor Equity capital	Imputed noncash costs, plus
Operator management Entrepreneurship or other residual claimants	Profits or return to management and entrepreneurship
	Equals gross income

From an economies-of-size perspective, they can be varied to change the output of a given size of farm. These variable costs include seed, fertilizer, variable (operating) machinery costs, and custom hired operations. Hired labor is shown as a variable cost in this illustration; however, permanent full-time hired laborers may sometimes represent a fixed resource in the short run.

Machinery and Other Cash Costs. These costs relate to machinery ownership and other annual cash costs associated with a farm of a specific size and are generally considered fixed in the short run. Machinery costs are the annual costs of the machinery complement associated with the farm and include replacement costs, insurance, and taxes. Depreciation is often used to represent the annual cash machinery replacement costs shown in table 1 and will be treated as such in this report. Other fixed cash costs of farm ownership include real estate taxes and general farm overhead expenses. Since these costs are fixed over the shortrun planning period, they are responsible for most of the initial decline in per-unit SRAC as output increases.

Imputed Costs of Land and Operator Inputs. Estimating the costs associated with resources provided by the operator—operator and family labor, equity capital, management, and entrepreneurship—presents special problems because these resources are not purchased in the marketplace. Estimating the cost associated with land is a different problem because the market value of land—and its longrun cost—is bound up in expected product prices, speculative expectation of increases in land prices, and resource returns *(8)*. Madden discusses these problems in detail in his well-known economies-of-size report (*11*, pp. 14-17). Imputed costs are sometimes given to these factors based on their estimated marginal productivity or opportunity costs. However, there exists no single "correct" method of imputing these costs and the various methods yield vastly different costs *(16, 18)*.

To avoid arbitrary imputation procedures, these factors are sometimes assigned the residual returns (profits) after other costs are paid. By definition, cash costs plus any imputed noncash costs plus profits (or losses) always equals gross income, as shown at the bottom of table 1. The dashed line in the last section of table 1 denotes an arbitrary partition. Each of the factors in the bottom of table 1 can either be classified as a cost (imputed) or residual claimant. For example, land, which is shown in the table with an imputed cost, could be moved below the dashed line where it would receive the residual return along with management and entrepreneurship.

Madden illustrates cost calculations based on different residual claimants (*11*, table 1, p. 16). Some farm cost analyses treat all these factors as residual claimants (and compute net farm income or return to land and operator inputs). Other analyses impute costs to land, operator labor, and management and treat only entreprenuership as a residual claimant (profit); and some studies choose an alternative between these two.

This imputation and partitioning process and the resulting profit concepts have an important implication for economies-of-size studies. The choice of the residual claimant affects both the level of longrun average cost curves and the slope or tilt of these relationships (*11*, p. 15). In other words, the specific choice of which costs to impute and the resulting residual claimant can change the most efficient farm size determined by empirical research. As more factors are given inputed costs, the cost-return ratio increases (the LRAC curve shifts upward) and the LRAC curve tilts with larger farms appearing more efficient compared with small farms. In particular, imputing a high cost to unpaid operator and family labor guarantees that small farms will appear less efficient than large farms.

Problems with Imputing Land and Operator Input Costs

Questions about cost concepts are critical for economies-of-size studies. Numerous procedures exist and the choice of a procedure or definition can significantly affect the results. Land and operator labor present special problems for imputing costs. The critical nature of these problems warrants a closer inspection of economic theory for clues to the most appropriate research methods.

Land Costs and LRAC Relationships. The price of agricultural land and its cost to the farm in the short and long run are related to farm product prices and net farm income.[3] The theoretical relationship be-

[3]Land prices are influenced by many factors, only one of which is current return from farming. Government farm programs, the higher use potential (outside agriculture) of some land, expectations of future farm income increases, and speculation and the expectation of future capital gains from land value increases often overshadow farming returns in determining land prices *(14, 21, 23)*. These factors are, however, beyond the scope of economies-of-size studies. This report will consider land price in the limited sense of its use in farming and the component of price based on current farming returns. Other components of land price, which are often added to this "agraicultural price," have little relevance to economies of size.

tween farm product prices, the agricultural value of land, and land costs is illustrated in figure 2 (5, pp. 96-101). The left side of the figure shows the SRAC curve and associated LRAC curve for the most efficient farm while the right side shows the industry product supply and demand relationships.[4]

The LRAC curve in figure 2 includes a normal profit and return to all nonland resources necessary to retain them in production in the long run. The supply of the land resource to the industry is assumed fixed and its cost is not included in LRAC. Instead, land earns the residual return or economic rent, as follows. At equilibrium in the long run, each farm is at a similar size with an output corresponding to the low point on the LRAC curve, or point F. The SRAC curve corresponding to this size is shown on the graph with the associated marginal cost curve (MC). Industry demand is shown as D_1, and for this level of demand the market clearing price that equates supply and demand is P_1, with each farm equating MC and P_1 at D. This price exceeds the LRAC of variable resources and the excess returns, DE, is defined as the economic rent to the fixed factor, land; it represents the residual return assigned to land.

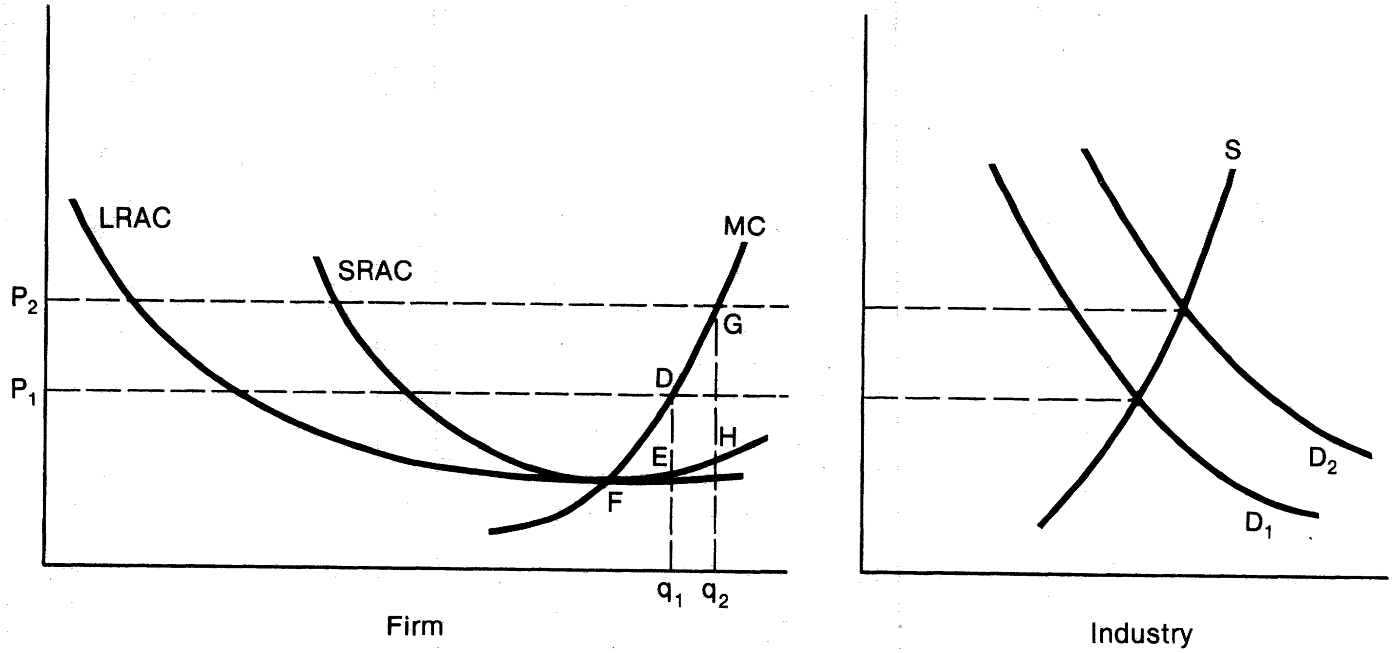
This economic rent, DE, represents the current agricultural earning of land. Through the capitalization process, it becomes one of the key determinants of the agricultural value of land. For example, a $100-per-acre residual return, capitalized at 10 percent, results in a land value of $1,000.

Changes in product prices are related to land values in the following manner. An increase in demand to D_2 in figure 2 in the short run causes farms to expand production to q_2, equating the marginal cost of production with the higher price. This adjustment represents the intensive margin with respect to land, with each farm in the industry applying more inputs to its fixed land base. If D_2 becomes the expected longrun level of demand, the increased rents earned by land, GH in this example, become capitalized into land values. In this example, the agricultural value of land would increase by the ratio of GH to DE. Farm sizes and numbers change little since the minimum point on the LRAC relationship

[4]The figure is based on the usual assumptions of economic theory for a perfectly competitive industry. It assumes there are no externalities either in production or consumption. Input market prices are assumed to correctly reflect resource values and scarcities. Freedom of entry and resource mobility are assumed, thereby assuring that the industry-supply functions for all resources except land are perfectly elastic.

Figure 2.

Relationship Between Farm Product Prices, Farm Costs, and Industry Equilibrium Conditions



would not be changed but more inputs are applied to each acre of land.[5]

Downward adjustments in demand have the opposite effect as long as the equilibrium price exceeds the minimum LRAC curve covering variable nonland resources. At a price that equals the low point of the LRAC curve, F, land would earn no economic rent but all other costs would be covered. Further declines in demand and product prices would cause production to be unprofitable, farms would leave the sector, and the industry supply function would shift to the left to a point where product price equaled the longrun average costs for the remaining farms. This adjustment is along the extensive margin of land. In this situation, land is in surplus and would flow into and out of the industry in the same manner as other resources.

The economic theory depicted in figure 2 suggests that when the industry is in equilibrium, all land earns a corresponding rent, and the LRAC for variable resources plus the economic (land) rent equals the product price. The agricultural price of land stabilizes at a level that corresponds to its agricultural value, and land earns an agricultural return in the long run corresponding to the capitalization rate used by landowners.

This theoretical example, with the supply of land assumed fixed to the industry in the long run, indicates that land must be treated as a residual claimant in estimating LRAC; no cost can be imputed. Alternatively, when the industry supply of land is completely variable in the long run (economists call this perfectly elastic) some opportunity cost concept may be appropriate.[6] Essential to the question of whether land earns an economic rent or should be given an imputed opportunity cost in economies-of-size studies is the definition of the industry. The way the industry is defined affects the elasticity of the land supply function. Two approaches are possible—defining industries on a commodity basis or defining industries on a multi-commodity, type-of-farm basis. In both cases, the definition of an industry must be location specific. Because technical production processes vary enough by region to result in differing LRAC relations, an economies-of-size study done in the Columbia Basin would not necessarily be valid for Kansas, or vice versa.

Examples of commodity-based economies-of-size studies in a specific region would perhaps focus on the wheat industry, the corn and/or feed grains industry, or the beef industry. While there may be overlap, with some farms participating in more than one of these industries, these economies-of-size analyses would be useful in understanding cost efficiencies in the production of individual commodities. With this definition of an "industry," the supply of land available to the specific industry is by no means fixed; instead the amount of land available to the industry could change as land is bid away from one enterprise to another. For example, the cost of land for wheat would be its opportunity cost in a competing enterprise such as barley.

Alternatively, the definition of the industry could be certain types of farms in a region—economies of size on corn-hog farms, cotton-soybean-wheat farms, or field crop farms. This definition may avoid a "fallacy of composition" which could arise from looking at individual commodity efficiency studies. While land is a variable resource in the sense that each individual commodity production process competes for land on each farm, it is incorrect to assume that land is a variable resource for all farms in the region. Thus, while cropland would be variable as far as wheat production is concerned, it would be fixed for all wheat-feed grain farms in a region. This type-of-farm definition of farms and industry would warrant treating land as a residual claimant in economies-of-size studies.

Labor Efficiency and Economies of Size. Imputing a cost to operator and family labor presents another difficulty when estimating longrun average costs. There is no doubt that the labor efficiency of large machinery lowers the hours of labor per unit of output on large farms. Nevertheless, a procedural question exists concerning how to translate this labor efficiency into economies-of-size estimates when the labor is provided by the operator and family and is not purchased in the hired labor market. Either a reservation price or an opportunity cost must be related to this operator and family labor to convert this physical labor efficiency into some economies-of-size concept.[7]

[5]Figure 2 shows farm size measured in output (gross income). While the most efficient output level would not change in the new longrun equilibrium, longrun adjustments on the intensive margin could involve small changes in land per farm, depending on the longrun elasticity of substitution between land and other inputs.

[6]Conceptually, opportunity cost is the highest return a resource can earn in any alternative use currently available.

[7]Opportunity cost is usually assumed to be the market rate of return, such as current hired labor wage rates for operator and family labor. Some resources do not have any effective opportunity cost, in the sense that the market rate of return is less than adequate to retain the resource in use. In these cases, the reservation price becomes relevant as the lowest return below which the resource will simply retire from use.

In previous economies-of-size studies, the general procedure has been to impute a cost per hour of operator labor on all farms equivalent to the hired labor wage rate (7, 11). Madden argues, however, that the opportunity cost of operator labor is likely to be relatively low for some small farmers who lack the skills, education, and mobility to be attracted into off-farm employment (11, p. 18). Madden's proposal for viewing the farm as a goods and services firm implies that the opportunity cost of all available operator labor hours should not be charged against small farms. Excess labor as well as machinery capacity is often sold to another firm, particularly in the form of a part-time, off-farm job or custom machine work.

Holland questions studies, such as the one by Hall and LeVeen, which charge a fee of $20,000 per year for unpaid family labor, and asks whether it is reasonable to attach such a high labor opportunity cost to small farms (6, 4). Miller and Skold (16) and Pasour (18) have discussed the arbitrary processes involved in imputing residual returns to operator labor. These studies do not represent a consensus of how to include labor costs in empirical economies-of-size estimates.

For empirical LRAC estimates, many different classes of farms are represented along the curve, and many different opportunity costs are represented. Arguments that these opportunity costs vary by size of farm include:

- The number of small hobby farms is increasing. Because such farms are essentially leisure time activities, the reservation price on operator labor is likely very low, or even negative.

- Large capacity, complex machinery requires highly skilled operators, compared with the smaller, older, and less complex machinery found on smaller farms. This fact suggests both higher quality and higher imputed costs of operator labor on larger farms.

- USDA estimates that 60 percent of the income of farm families comes from off-farm sources and this figure is much higher on small farms. This substantial off-farm income is *de facto* evidence that small farm operators do not require a full-time equivalent opportunity cost for the time devoted to the farm—support for Madden's goods and services concept.

- The viability and efficiency of a home garden, with its attending low opportunity cost on labor, is an extreme but illustrative example. Such endeavors may be relatively efficient in an economies-of-size sense even though they require much more labor per unit of output than large, mechanized vegetable farms.

In summary, the opportunity cost or reservation price of family labor likely varies by size of farm. But since it is a subjective concept for each farmer and is not observable by the independent analyst (18), it is extremely difficult to make an empirical measurement of this relationship. Higher per-unit labor requirements on small farms in some cases contribute to higher average costs. In other cases, this inefficiency is balanced or offset by lower labor opportunity costs, including free labor and management in some cases. Identifying the most likely of these two possibilities—or an appropriate mix of the two—presents a difficult research challenge. A review of existing studies and economic theory leaves numerous questions unanswered and a considerable amount of indeterminacy in procedures.

Costs of Other Operator Inputs. The other resources provided by the operator—equity capital, management, and entrepreneurship—present similar cost imputation difficulties (18). In some cases, a market exists for these resources; in other cases, they are unique to a specific operator and farm. While empirical measurement is similarly difficult, some opportunity cost or some reservation price may apply as with operator and family labor. Similar questions also exist concerning whether these opportunity costs or reservation prices vary by size of farm. For example, the management function is more difficult on large operations requiring supervision of more hired labor and coordination of a highly complex operation; and this difficulty would appear to justify either a higher opportunity cost or a higher reservation price as farm size increases.

A cost is often imputed for the operator's equity capital based on its opportunity cost—the interest rate. This procedure presents special and often overlooked problems when inflation rates are high because real, not nominal, interest rates represent the opportunity cost of capital (29, 36). While the nominal rate of interest is observable in the market, the real rate (nominal interest rate less the inflation rate) is difficult to estimate for the future. Real interest rates have been very low during the seventies, so the opportunity cost of equity capital is probably not a significant factor in economies-of-size studies.

As another option, it may be argued that all operator input services, including labor, management, and entrepreneurship, are the only truly fixed resources of the farm in the long run. In fact, more land can be rented or purchased, while entrepreneurship and management are fixed with the individual operator. In this case, these inputs fall in the category of residual claimants and no imputed cost should be used for empirical LRAC estimates.

Cost Definitions for Specific Purposes

Consideration of the specific uses of economies-of-size estimates provides some guidance concerning appropriate cost definitions. In general, it may be argued that economies-of-size studies are not intended to identify the level of the LRAC curve. Questions about the magnitude of costs, and how such costs relate to the well-being of agriculture, are better answered by other indicators such as farm income, return to equity, balance sheets, and cost of production. Empirical estimates of economies of size do not provide information on the well-being of farmers; the major purpose of such estimates is to show relationships between farm size and efficiency. Several cost definitions may be useful.

Longrun Average Cash Costs—$\mathbf{LRAC_1}$. Economies-of-size estimates based on longrun average cash costs serve some purposes. These longrun average cash costs include the items identified in the top section of table 1 and are denoted by $LRAC_1$. With this cost definition, land, equity capital, and operator inputs—labor, management, and entrepreneurship—are considered residual claimants and their imputed costs are not included. The difference between $1.00 and the LRAC curve is the return to these residual claimants per dollar gross income. Since depreciation is included as a "cash" cost in the top section of table 1, this residual is analogous to the net farm income generated per unit of gross income.

This $LRAC_1$ curve has several uses and interpretations. For each farm size, the difference between the $LRAC_1$ and $1.00 represents the maximum net farm income per dollar gross income that can be achieved under the specified conditions. Therefore, the $LRAC_1$ concept indicates the net income producing capability of farms of different sizes. Secondly, the resulting "breakeven size"—where the $LRAC_1$ curve goes below $1.00—represents the smallest size at which farms are able to continue operation since gross income just covers cash costs at this point. Farms of this size are able to cover cash costs but the residual returns to land and to operator inputs are zero. Such comparisons relate to the "survivability" of small farms.[8]

Third, since it shows the relationship between economies of size and economic rent, $LRAC_1$ is the best concept to ascertain the extent to which public policy restrictions on the size distribution of farms may affect residual returns to operator and family labor, management, entrepreneurship, owned land, and equity capital. Thus this cost definition is the most appropriate for analyzing the effect of the Department of Interior's proposed 160-acre limitation *(13)*. Some analysts have argued that the major effect of this limit will be to reduce returns to land *(4)*.

Longrun Average Cash Costs and Operator Labor—$\mathbf{LRAC_2}$. A second economies-of-size cost concept adds the imputed cost of operator and family labor to the cash costs, and leaves equity capital, land, management, and entrepreneurship as residual claimants. This definition of costs is denoted by $LRAC_2$. Operator labor cost would be represented by either the imputed opportunity cost or the reservation price, whichever is higher. Adding the reservation price or the opportunity cost of operator labor to the $LRAC_1$ curve provides a longrun cost that, when compared to the price line, estimates a return to land, equity capital, management, and entrepreneurship by size of farm. This definition is analogous to the one used by a USDA study of returns to equity by economic class of farm *(7)*.

From a farm planning perspective, the opportunity cost or the reservation price for operator and family labor are usually known (or expectations can be formed), and the $LRAC_2$ curve then becomes relevant for long-range planning. Some small farmers have a definite opportunity cost on their labor, such as an off-farm job that provides a real alternative to farm work, and others have a reservation price equivalent to their value of leisure. An economies-of-size estimate including the appropriate imputed labor cost can help them decide whether to exit from agriculture or expand their size of operation.

[8]This conclusion is valid for constant land prices but not when there is continuing inflation in land prices. With increasing land prices, farmers are encouraged to stay in farming to capture gains even though total revenue may not cover total cash costs (11, p. 17).

(Again, the expectation of increasing land values may make it prudent to continue farming, even in cases where the $LRAC_2$ exceeds \$1.00 per dollar of gross income for the farm in question.)

Part-time farmers, who farm as a hobby or leisure activity with labor not required because of their off-farm job or business, would have labor reservation prices approaching zero. Of course if they expand the labor input for the farm to the point where they have to quit or reduce their off-farm employment, a higher opportunity cost would become relevant. The $LRAC_2$ curve may relate to the "survivability" of such farms, namely those where the operator has meaningful opportunities for alternative employment that compete with essential farm work.

Farm managers, in longrun planning on size of plant, use this cost definition to determine how technical factors may affect cost efficiencies as the size of their farm changes. If substantial economies of size exist, farmers want to move toward the size of unit that achieves these economies. If few size economies exist, they are interested in assurance that diseconomies will not reduce their initial cost efficiencies as they expand.

Society may have an interest in farm labor returns in assuring that all resources are used in the industry where their return is greatest. The opportunity cost to society of having farmers under-employed on small farms may be high, even though such farmers place a low, even zero, reservation price on their own labor. The social opportunity cost of farm operator labor would represent the alternative opportunities for the labor resource in other industries. In this case, an appropriate $LRAC_2$ concept would result in a "social economies of size" estimate. Of course in an economy of unacceptably high unemployment rates and increasing negative externalities of urban living, the "social opportunity cost" of farm operator labor may be quite low.

Longrun Average Cash Costs, Operator Labor, and Economic Rent—$LRAC_3$. A third economies-of-size cost concept covers cash costs, the imputed value of operator and family labor, and a return to land and all other factors provided by the operator. This definition of total costs is denoted by $LRAC_3$. One estimate of the "equilibrium rate of economic rent" is implicit in economies-of-size studies. Economic theory holds that, in equilibrium, the low point on the longrun average cost curve is the point where revenues are just equal to costs, and at this point all factors of production are earning a normal return. In equilibrium, abnormal profits do not occur and all resources earn a normal return on the most efficient size of farm. Tweeten describes this situation for farming—in the long run, the most efficient farms bid up the price of resources so that their total cost just equals gross income (*30*, pp. 184-189). Imputing this return rate as a cost to all farm sizes results in $LRAC_3$, a cost definition that serves some additional purposes.

Barriers to entry, generally because of high land prices, represent a special problem in the structure of agriculture (*33*, p. 116-120). $LRAC_3$ may be of use here. Entering farmers who must pay the current market value for land, face costs that approach $LRAC_3$, although they may impute lower costs to operator labor, management, and entrepreneurship than the most efficient farmers. Nevertheless, a new farm must be relatively large and efficient to cover these high land costs. In the absence of nonfarm income and with constant land values, $LRAC_3$ indicates what sizes of new farms are likely to enter the industry.

The $LRAC_3$ concept can also be used to illustrate part of the "intergenerational dynamics" of structural change. Existing small farms with completely owned land operate on $LRAC_1$ relationships and can survive indefinitely as long as $LRAC_1$ is below \$1.00. Such farms often may be passed from one generation to the next without affecting these cost definitions. However, when such a farm is sold to a new entrant, all costs must be considered and $LRAC_3$ becomes relevant, since land debt must be paid out of current income. Thus, while existing small farms may have substantial survivability, transfers of these farms to new farmers may be infeasible.

Method of Study

Of the several approaches that could be used to study economies of size, the economic engineering approach was chosen for this report (*11*, p. 29). This approach is similar to the one used in many other economies-of-size studies and uses a cost minimization linear programming model to estimate farm SRAC curves. The longrun average cost curve is then estimated by plotting envelope points of tangency on the SRAC curves. Alternative cost definitions were used to estimate $LRAC_1$, $LRAC_2$, and $LRAC_3$.

The Model

The linear programming model was designed to study whole farms with multiple products by determining the least cost mix of enterprises required to produce specified levels of gross income. For each specific farm size, the SRAC curve was estimated by computing the minimum cost solution at each of many specified gross income levels; these solutions correspond to varying degrees of utilization of a fixed plant.

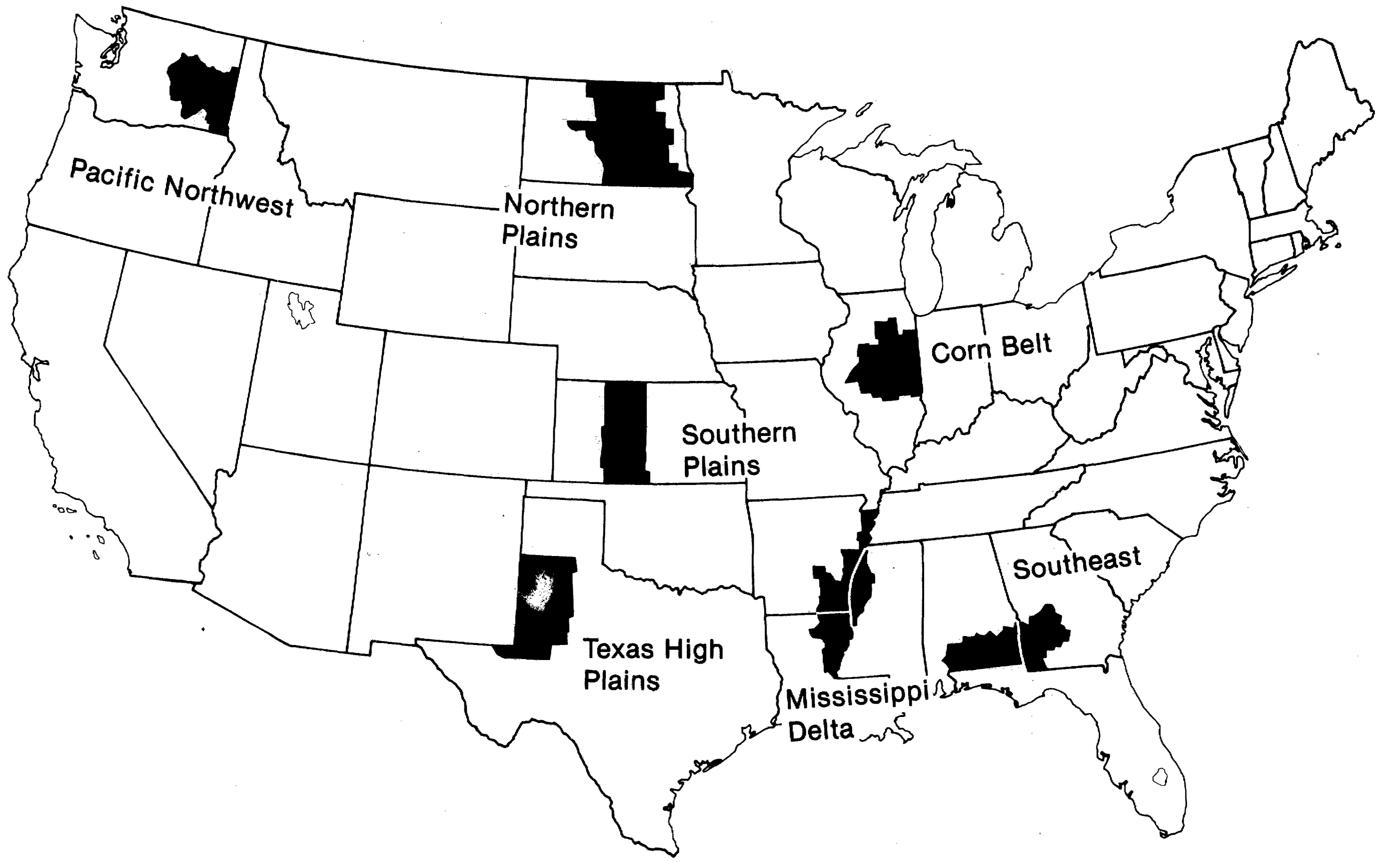
The algebraic formulation of the linear programming model is presented in the appendix. The specific model developed for this study treats the machinery complement as the primary fixed resource and machinery time and operator labor as the primary resource constraints. Both of these resources were constrained by time periods corresponding as nearly as possible to the actual time constraints faced by farmers in each region. For each SRAC, gross income was varied in discrete steps (of $1,000 to $5,000) up to the maximum that could be obtained with that machinery complement. The model determined the least-cost solution and the associated cost-per-dollar gross income at each step.

Assumptions of the Study

The economies-of-size study focused on seven regions (fig. 3). Typical field crop enterprises in these regions represent the major wheat, feed grain, and cotton producing situations:

Figure 3

Location of Economies-of-Size Study Regions



Corn Belt—corn, soybeans, winter wheat, oats

Pacific Northwest—winter wheat, barley

Southeast—peanuts, cotton, corn, soybeans

Southern Plains—winter wheat, grain sorghum

Texas High Plains—cotton, grain sorghum

Northern Plains—durum wheat, other spring wheat, barley

Mississippi Delta—cotton, soybeans, grain sorghum, winter wheat

Hypothetical study farms were developed for each region to represent conditions and practices unique to the region and in some cases, unique to a particular size of farm within the region. The primary source of information on farming practices, machinery complements, and costs in the different regions was the 1978 Firm Enterprise Data System (FEDS) cost of production survey conducted by the USDA (*32*, p. v).

Farm Size Assumptions. Four study farms were defined in each region for estimating the SRAC curves. The study farm sizes were determined in two stages: selection of the initial size intervals, and the determination of the final study farm size by the linear programming model. The initial size intervals were used to group the FEDS Survey data by size interval, identify the specific machinery complements for each farm size, and set up the linear programming models.

Appendix tables 1 through 7 show 1974 Census of Agriculture data on farms in various farm size intervals and the numbers of farms surveyed in each interval by the 1978 FEDS cost of production survey. The four study farms in each region were initially developed to correspond to the smallest 25 percent of farms, the next 25 percent, and so on, based on cropland. Thus the interval bounds between farms A, B, C, and D approximate the 25th, the 50th, and 75th percentiles of cash grain farms shown in the 1974 Census of Agriculture. These intervals were adjusted in some cases to correspond more closely to the FEDS Survey counts shown in the middle of the appendix tables. The initial farm sizes were selected to be representative of farms within the intervals. Thus, the initial study farms at the bottom of appendix tables 1 through 7 correspond to the following 1974 census size percentiles:

Study farm size	*Percentile*
A	21 - 34
B	42 - 53
C	66 - 72
D	83 - 89

For example, 21 to 34 percent of the actual cash grain farms in each region were smaller than the size A study farms; 42 to 53 percent of actual farms were smaller than the size B study farms, and so on.

The final sizes of the study farms were determined by the linear programming model as the acreage providing the most efficient utilization of the (fixed) machinery complement. While total owned land was constrained in the model, each farm was also allowed to rent additional land to fully utilize the machinery available. Land rental rates for this purpose were set to equal the annual cash costs of owned land, so that the initial farm acreage and final proportion of land rented would not bias the economies-of-size estimates. This procedure assured that the machinery complement for each farm would be utilized on the most efficient acreage of cropland.

The final sizes of the study farms represent the low points on the SRAC curves in each region (table 2). Most of the additional cropland was added to the largest study farms. While the Census of Agriculture intervals showing the size distribution of cropland are too wide to permit accurate interpolation (*35*), the final sizes of the largest study farms approximate the following percentiles: Corn Belt, 92; Pacific Northwest, 91; Southeast, 90; Southern

Table 2—Final cropland acres on study farms

Region	Farm A	Farm B	Farm C	Farm D
	Acres			
Corn Belt	77	141	272	639
Pacific Northwest	120	290	630	1,887
Southeast	61	130	160	399
Southern Plains	200	360	607	1,488
Texas High Plains	115	281	500	974
Northern Plains	232	402	683	1,476
Mississippi Delta	86	164	413	1,237

Plains, 96; Texas High Plains, 94; Northern Plains, 92; and Mississippi Delta, 91.

Resource, Cropping, and Management Practices. Prevailing cropping and management practices were identified for each region and the study farms were developed to assure that model results were achievable from technical, economic, and agronomic standpoints. The conditions and practices selected for each region are described in detail in the appendix of this report, together with the procedures and supporting data.

Readers with specific interests in this information should turn to the appendix. Topics covered include identification of labor, tractor, and machine time constraints; constructing the regional crop enterprise budgets; selection of activities for the linear programming model; information on yields and prices; and estimation of machinery fixed costs.

The primary source of data for all of these items was the 1978 cost of production survey conducted by USDA, the associated FEDS crop enterprises, and typical farm budgets *(32, 28)*. The FEDS data were supplemented where necessary with data from other secondary sources, particularly from agricultural experiment stations in the respective regions. The FEDS budget data were also used for all input costs and all prices received.

Costs and Income on Study Farms. The procedures and assumptions described above and in the appendix provide the critical cost data for estimating economies of size. Costs of production for the four study farms in the Pacific Northwest region are shown in table 3. Similar cost information for the other six regions appears in appendix tables 10 through 15. The total cash operating costs (variable costs) show the magnitude of these costs on the study farms with an optimal enterprise mix. Since these costs vary with the intensity of farm operation, they correspond to only one point on the SRAC curve for each farm; the most efficient level of operation has been selected for this example. The machinery costs and other fixed costs represent the fixed costs associated with the respective farms, regardless of the level of operation. Gross income at the most efficient level of operation is shown at the bottom of the tables.

Limitations of FEDS Data

The use of the 1978 FEDS Survey data for cultural practices and input information resulted in a thin data base for some of the small farms (see appendix tables 1 through 7). The data base is thin at these sizes because the sampling design of the 1978 FEDS

Table 3—Cash operating costs and gross income on study farms—Pacific Northwest

Item	Farm A	Farm B	Farm C	Farm D
	Dollars			
Land rent	0	0	2,499	0
Hired labor	0	0	0	1,773
Seed	411	947	2,071	3,378
Fertilizer and chemicals	1,672	4,835	9,390	18,320
Machinery repair and maintenance	559	1,201	2,409	5,235
Machinery fuel and lubrication	330	649	1,221	3,021
Interest on operating costs	218	515	875	2,052
Total cash operating costs	3,190	8,147	18,465	33,779
Machinery replacement costs	3,969	7,750	13,232	21,931
Taxes on machinery	151	287	499	802
Machinery insurance	168	311	430	605
Total cash machinery costs	4,288	8,348	14,161	23,338
Real estate taxes	464	1,113	1,044	5,669
General farm overhead	2,010	4,858	10,553	25,260
Total other fixed costs	2,474	5,971	11,597	30,929
Total cash costs	9,952	22,466	44,223	88,046
Gross income	14,421	34,851	75,712	155,617

Survey selected farms on the basis of size and not on the basis of farm numbers. Since each acre of crop surveyed had an equal probability of being chosen, this led to an emphasis of large farms in the sample.

This large farm bias made it necessary to use secondary data sources to develop some of the crop enterprise budgets on some smaller farms. In addition to the lack of data for some enterprises, there were only a limited number of observations on enterprises in the two smaller study farms in some regions. The resulting shortrun cost curves on these small farms may not be accurate.

The results of this study depend in large part on the age of the equipment in the machinery complement and the proportion of that equipment that is purchased used. In this study, 55 to 70 percent of the equipment on small farms was purchased used. With new equipment, per-unit costs would have been substantially higher on the smaller farms. Likewise, the age of the used equipment has a bearing on the cost level, since older, used equipment has increased variable (repair) costs and lower fixed costs. The net result of the older, used equipment on the small study farms is to lower total machinery costs.

The 1978 FEDS Survey provided little data except for the age and used purchases of tractors. This data limitation and the possible errors introduced by the assumptions in the analysis mean that the actual LRAC curve may be either higher or lower for the small farms than the estimates shown in this report.

Questions concerning crop yields on small farms may also have a bearing on the shape of the curve. In some regions, the FEDS data suggested that farms of different sizes used different input quantities. Information was not collected, however, which would provide an evaluation of yield differences by size of farm. The study assumed that all farm sizes had the same yield.

Market economies were left out of the calculation of the cost curves. Since the 1978 FEDS Survey did not provide any information on market economies, several assumptions were necessary to cover these data gaps, mainly that large farms experience no price advantage over other farms regardless of quantities bought or sold. Other studies have focused on market economies and found them to be significant in some sectors *(9, 10)*. Additional research on market economies is in the planning stage in USDA.

The FEDS Survey data provided no information about the economies or diseconomies associated with management. Seckler, Sparling, and Madden have discussed possible management diseconomies associated with large-scale farming operations *(24, 27, 11)*. Generally these diseconomies result from the difficulties encountered in managing a large number of hired workers and the uncertainty and complexity of decisionmaking on large farming operations. But since data on management costs by size of farm are not available from the FEDS Survey, this report assumes that all farms operate with the same level of management and ignores the possibility of such diseconomies. The net result of these data gaps is that the LRAC curves estimated in this report likely do not include all economies and diseconomies faced by actual farms.

Results of the Analysis

Shortrun average cost curves were estimated for the four study farms in each region using the study methods described in the previous section. The longrun average cost envelope curves were then developed from these shortrun average cost estimated in each of the seven regions (fig. 4-10). Each figure shows three longrun average cost curves based on the alternative cost definitions discussed earlier in this report.

Longrun Average Cash Cost Curves—$LRAC_I$

The lower curves in each figure include only variable and fixed cash costs, and represent longrun average cash costs ($LRAC_I$) as defined earlier. No charge is made for operator labor or management and no land rent or return is included. The difference between these $LRAC_I$ curves and the $1.00 line represents the net farm income generated per dollar of gross income by farms of different sizes.

As shown, the $LRAC_I$ curves for all seven regions have relatively little slope and do not turn up to any great extent for small farms. For the largest farms, the curves show little slope between the third and fourth study farms and no data were available from the FEDS Survey on management economies or diseconomies. Also, no information was available on market economies on large farms. With these data limitations, the analysis of an additional larger farm size would not have revealed much about the shape of $LRAC_I$ curves beyond study farm D in each region.

Figure 4.

Longrun Cost Curves for Grain Farms in the Corn Belt, Assuming Different Residual Claimants

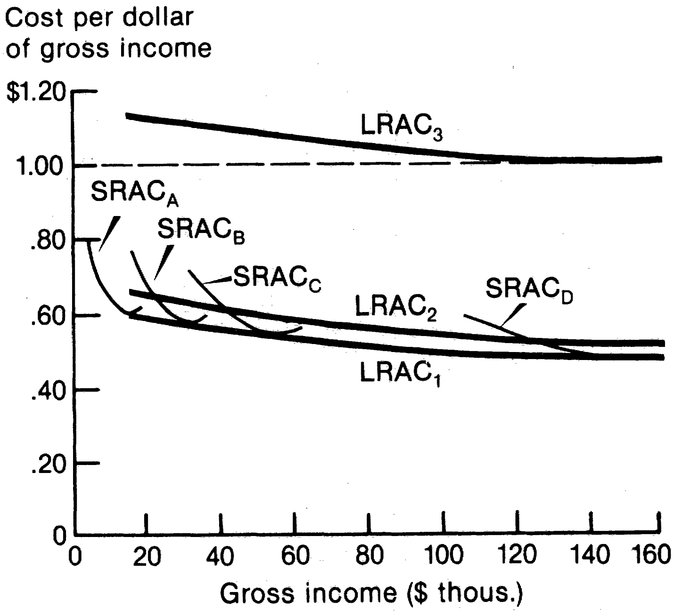


Figure 5.

Longrun Cost Curves for Grain Farms in the Northern Plains, Assuming Different Residual Claimants

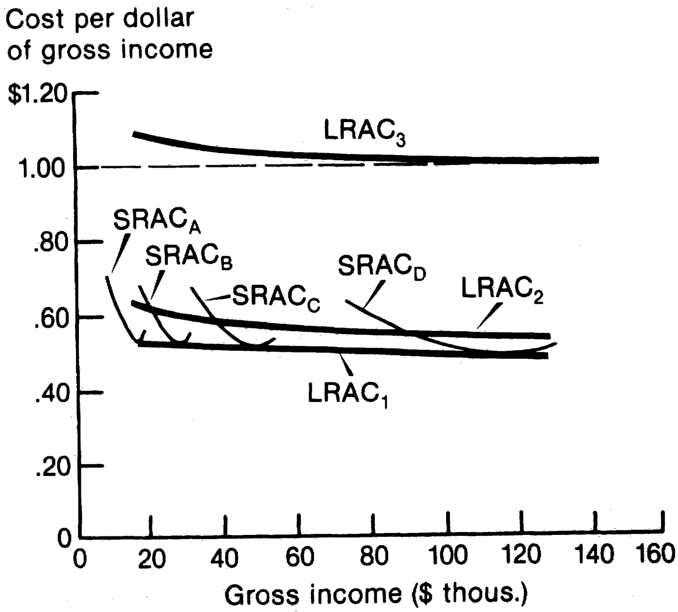


Figure 6.

Longrun Cost Curves for Grain Farms in the Pacific Northwest, Assuming Different Residual Claimants

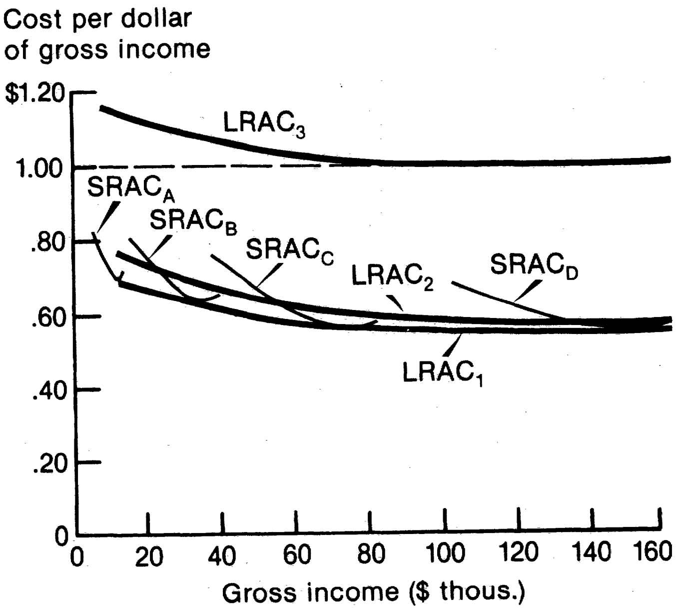
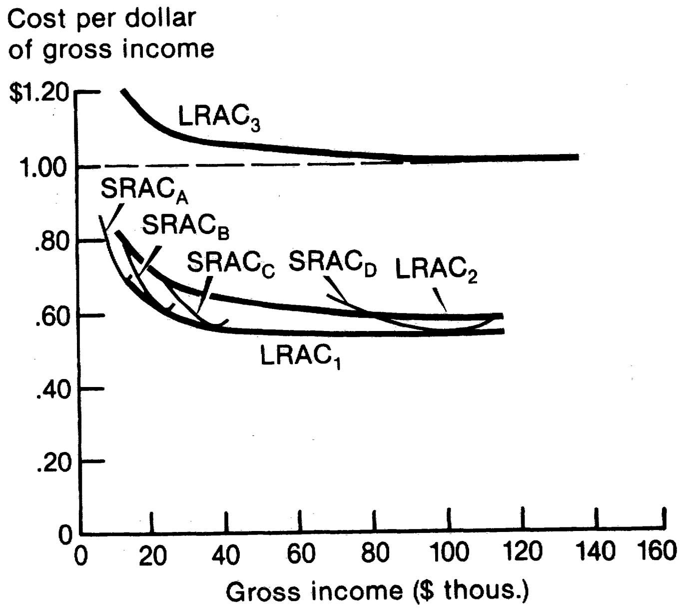


Figure 7.

Longrun Cost Curves for Grain Farms in the Southern Plains, Assuming Different Residual Claimants



For cotton farms in the Mississippi Delta (fig. 8) and the Texas High Plains (fig. 9), $LRAC_1$ curves range from $0.76 to $0.86 per dollar of gross income and exhibit relatively few cost economies on large farms. The other regions generally have $LRAC_1$. curves in the $0.50 to $0.70 range, with economies of size most notable in the Corn Belt (fig. 4), the Pacific Northwest (fig. 6), the Southern Plains (fig. 7), and the Southeast (fig. 10). Even in these regions, cost economies are less than $0.16 over the entire range of sizes studied. In no case does $LRAC_1$ exceed $1.00—the smallest farms studied in each region can meet the specified cash costs out of farm income and additionally provide some residual return to operator labor and management inputs and to land.

Table 4 shows the cost increases on the smaller study farms, compared with the most efficient study farms. The regions in this table are in order of the importance of the size economies found on farm B of each region. These farms generate gross incomes of $25,000 to $45,000 and represent the smallest commercial farms—farms capable of supporting a farm family without considerable off-farm income. The comparison of the size B farms with the most efficient farms is an important measure of relative economies of size.

The costs of study farm B in each region range from $0.027 to $0.094 higher than the costs of the most efficient study farm (table 4). These differences are rather small when considered in light of the wide range of gross incomes represented between the size B and size D study farms.

The $LRAC_1$ curves are relatively flat in the Northern Plains and Mississippi Delta regions, with costs declining less than $0.05 per dollar of gross income over the entire range studied (table 4). In these regions, appropriately sized machinery complements on the smallest farms achieved nearly all of the cost efficiencies obtained on larger farms. In fact, variable machinery costs, such as fuel costs per crop acre, are generally the same for small farms as for large farms. Other cash inputs per acre—seed, fertilizer, and chemicals—are assumed to be unaffected by size of farm. Machinery fixed costs on small farms in these regions could be controlled by

Figure 8.

Longrun Cost Curves for Cotton Farms in the Mississippi Delta, Assuming Different Residual Claimants

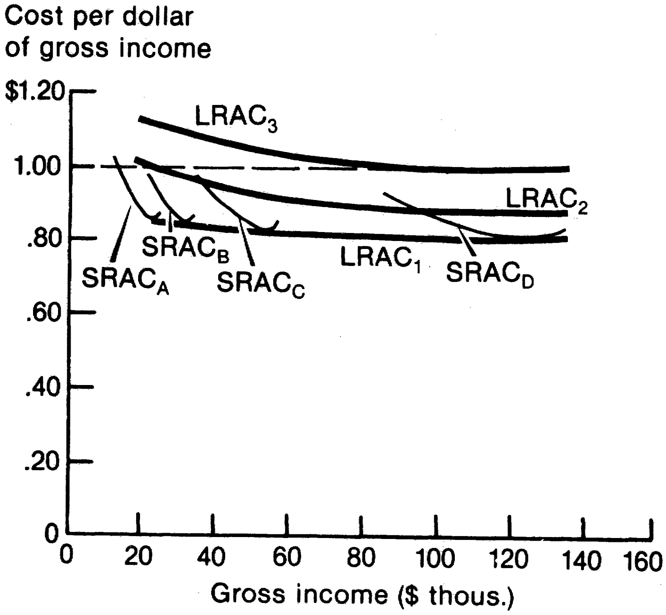
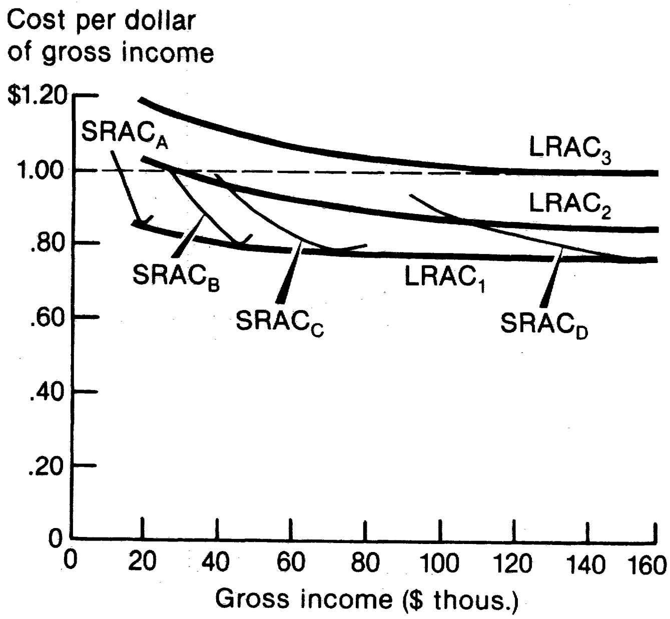


Figure 9.

Longrun Cost Curves for Cotton Farms in the Texas High Plains, Assuming Different Residual Claimants



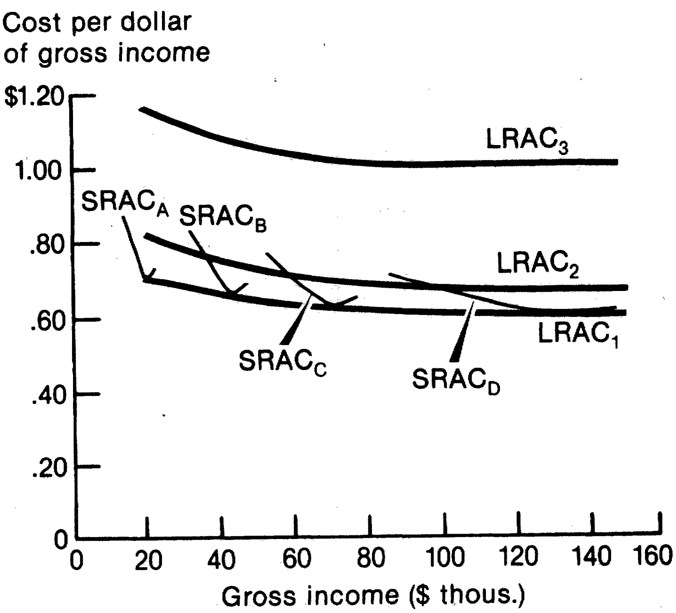
purchasing more used equipment and keeping it longer than is practiced on large farms.

In the remaining five regions, costs were from $0.09 to $0.16 higher on the smallest farms (table 4). In these regions no one factor appears to be responsible for these higher costs. The FEDS Survey data suggested fewer purchases of used machines and lower average age of machines in some of these regions. Increased use of higher costing custom-harvesting operations may also have increased costs on small farms in these regions.

Summarizing, the $LRAC_1$ curves shown in figures 4 through 10 and in table 4 exhibit relatively small size economies. Small farms with gross incomes in the $14,000 to $23,000 range have costs per dollar of gross income that are from $0.05 to $0.16 higher than the most efficient study farms. In no case do variable and fixed cash costs exceed gross income under the assumptions made on these study farms. The small commercial farms ($25,000 to $45,000 gross income) have costs that are $0.03 to $0.09 higher; medium-size farms ($41,000 to $76,000 gross income) have costs that are $0.02 to $0.06 higher

Figure 10.

Longrun Cost Curves for Peanut Farms in the Southeast, Assuming Different Residual Claimants



than the most efficient large farms. Even the largest of these cost differences appears minimal when compared with the wide range of farm sizes represented.

Longrun Average Cash Costs and Operator Labor—$LRAC_2$

The difficulty of estimating a charge for operator labor has been discussed in the section of this report on theoretical considerations. While a charge for operator labor is subjective, under special circumstances it may be useful to consider a longrun average cost curve which includes an opportunity cost for operator labor—$LRAC_2$ as defined earlier. Such a curve is shown in figures 4 through 10. In this case, an assumed opportunity cost of $4.50 per hour of operator and family labor was assumed for all farm sizes.[9]

More efficient labor use on larger farms is shown by a narrowing of the gap between the $LRAC_1$ and $LRAC_2$ curves as farm size increases. This narrowing is apparent in all regions (fig. 4-10). However, the use of custom harvesting on most small study farms to avoid high fixed machinery costs, also has the effect of reducing operator labor requirements. As a result, the quantity of operator labor used on small farms is less than what would be required without custom harvesting.

The opportunity cost covers only operator and family labor. On the larger farms, hired labor was used in addition to operator labor to allow the farms to reach higher gross incomes. A more accurate measure of labor productivity would be the total hours of labor required on the different farm sizes. Nevertheless, figures 4 through 10 suggest that the higher labor productivity on larger farms does not lead to large economies of size.

Table 5 shows data underlying the assumed operator labor opportunity costs. The top part shows operator labor hours used per $100 gross income on the different study farms. While some regional differences are apparent, the average for all regions drops from 2.12 hours on farm A to 1.20 hours on farm D, a decline of nearly one-half.

[9]If, as Madden suggests (11, p. 18), operators of larger farms have higher opportunity costs of reservation prices compared to small farms, the assumption or a constant charge for all farms biases the results in favor of larger farms. That is, the assumption of a constant operator labor cost overcharges small farms in comparison to large farms.

The bottom part of table 5 shows the level of $LRAC_2$ costs on the study farms. The higher costs of the Texas High Plains and Mississippi Delta regions are apparent in this table. In these regions, a $4.50 opportunity cost charge for operator labor on small farms would nearly eliminate the returns to other residual claimants—equity capital, management, entrepreneurship, and land.

Longrun Average Cash Costs, Operator Labor, and Economic Rent—$LRAC_3$

The third cost curve shown in figures 4 through 10 includes longrun average cash costs, operator labor, and economic rent—$LRAC_3$ as defined in this report. As described earlier, economic theory holds that, in equilibrium, the low point on the LRAC curve is the point where revenues are just equal to costs, and at this point all factors of production are earning a normal return (economic rent). Imputing the rate of resource return obtained at this most efficient farm size as a cost to fixed factors on all farm sizes results in the "total cost" $LRAC_3$ curve shown on each figure. With this cost imputation procedure, the $LRAC_3$ curves show a $1.00 cost per dollar of gross income for the most efficient farms and higher per-unit costs for other farm sizes.

The procedure used here in defining $LRAC_3$, as well as the next section dealing with maximum rates of returns, requires estimates of the absolute low points of the longrun average cost curves. Results of this analysis do not provide a conclusive measure of the low point, since in no region does farm D have a higher cost than farm C. Nevertheless, several factors suggest that the unit cost of study farm D in each region represents nearly all available efficiencies:(a) the curves show little cost decrease from farm C to farm D; (b) the large machinery used on the large study farms means that further expansion requires duplication of machinery; and (c) increasing management diseconomies on even larger farms would likely offset any additional machinery efficiencies. While much larger farms may have approximately the same per-unit costs, the costs on study farm D appear to be near the minimum, given this study's procedures.

As described earlier, the $LRAC_3$ relationships with operator labor and an imputed return to all resources depict one of the "barriers to entry" faced by young farmers wishing to begin farming. Since they must compete with the most efficient sizes of farms in the acquisition of farm assets, the return to the current market value of these assets on the most efficient farms becomes a cost to all other farms (*30*, p. 187). From an economies-of-size standpoint, such farmers must enter agriculture with an efficient size unit or face unacceptably high costs.[10]

[10]Economies of size and the need for an efficient size of farm is only one barrier to entry in agriculture. High interest costs and land values, caused by inflation in the general economy, represent another more important barrier that is not reflected here. On the other hand, small farmers can lower some of these costs by accepting a lower rate of return on operator labor, management, and entrepreneurship.

Table 4—Gross income and $LRAC_1$ increases on smaller study farms compared to most efficient study farm

Region	Farm A		Farm B		Farm C		Farm D	
	Gross income	Cost increase	Gross income	Cost increase	Gross income	Cost increase	Gross income	Minimum Cost
	1,000 dollars	*Dollars*	*1,000 dollars*	*Dollars*	*1,000 dollars*	*Dollars*	*1,000 dollars*	*Dollars*
Corn Belt	16	+0.124	32	+0.094	53	+0.061	145	0.476
Pacific Northwest	14	+.124	35	+.079	76	+.018	156	.566
Southeast	20	+.102	43	+.060	70	+.017	130	.606
Southern Plains	14	+.158	25	+.057	41	+.021	100	.536
Texas High Plains	19	+.091	45	+.039	70	+.013	175	.760
Northern Plains	17	+.048	28	+.039	47	+.025	105	.483
Mississippi Delta	23	+.047	32	+.027	53	+.015	122	.816
Average, seven regions	18	+.099	34	+.056	59	+.024	133	.606

Table 5—Operator and family labor used per $100 gross income and $LRAC_2$ costs

Region	Farm A	Farm B	Farm C	Farm D
		Hours		
Hours of operator labor per $100 gross income:				
Corn Belt	1.24	0.57	1.12	0.73
Pacific Northeast	1.66	1.28	.65	.77
Southeast	2.18	1.63	1.56	1.14
Southern Plains	2.12	2.07	1.96	.96
Texas High Plains	4.10	3.71	2.91	1.92
Northern Plains	1.63	1.73	1.43	1.53
Mississippi Delta	1.89	2.90	2.21	1.37
Average, seven regions	2.12	1.98	1.69	1.20
		Dollars		
$LRAC_2$ costs per dollar gross income:				
Corn Belt	0.656	0.623	0.588	0.509
Pacific Northwest	.765	.702	.613	.600
Southeast	.806	.740	.693	.657
Southern Plains	.789	.686	.645	.579
Texas High Plains	1.036	.966	.904	.847
Northern Plains	.618	.600	.572	.552
Mississippi Delta	.990	.973	.931	.878
Average, seven regions	.809	.756	.707	.660

Sizes for 90-Percent Resource Return Rates

The low point on the $LRAC_1$ curves depicted in figures 4 through 10 approximates the farm size where the maximum rate of return to operator inputs and land is attained. Resource return rates on these farms are the highest obtainable in each region under the assumed conditions. But how much smaller can farms be and still approach this return rate? For example, how large must farms be to earn resource returns that are at least 90 percent of the maximum rate?

This size of farm is shown in table 6 for all regions, as gross income and as cropland acres. The right side of table 6 shows the income on these farms as a percent of the income on the most efficient farms. This gross income averages 33 percent in all seven regions, that is, farms approximately 33 percent of the size of the most efficient farms are earning rates of returns on resources that are 90 percent of the return rates on the most efficient farms. The reduction in acreage is more varied, with the less efficient farms averaging 322 acres or 28 percent of the cropland of the efficient farms. The difference between the percentage declines in gross income and the percentage declines in acreage is due to changing to a more intensive crop mix on small farms.

Farms averaging $46,000 gross income may be considered moderate by most size standards. Based on the $LRAC_1$ curves estimated in this study, such farms are capable of providing rates of resource returns that are within 10 percent of the maximum rates obtained with the most efficient farms. This decline in rate of return on moderate-size farms compared with large farms is only slightly smaller than that found by Hottel and Reinsel in their 1976 study (*7*); they found return rates of 6.9 percent on farms of $100,000 and over sales, compared with 5.9 percent on farms of $40,000 to $99,999 sales, a decline of 14 percent.

Averages for Seven Regions

The longrun average cost estimates for the different regions share many of the same characteristics. The general importance of economies of size in wheat, feed grain, and cotton production is illustrated by the averages for the seven regions (tables 4-6, fig. 11).

The seven-region average $LRAC_1$ curve declines from \$0.705 on farm A to \$0.606 on farm D, over a gross income range of \$115,000. If a uniform opportunity cost for operator and family labor is included, $LRAC_2$ costs decline from \$0.809 to \$0.660 over this size range. Figure 11 also shows the \$46,000 gross income level where resource return rates are within 10 percent of the rate on the most efficient farms.

The right vertical axis of figure 11 and the dashed line show the average net farm income earned by size of farm. This net farm income is computed as the difference between $LRAC_1$ and the \$1.00 line, multiplied by gross income. It ranges from an average of \$5,300 on the size A study farms to an average of \$52,000 on the size D study farms. Since the $LRAC_1$ curve is relatively flat, net farm income is nearly proportional to farm size and increases at a constant rate over the sizes of farms studied.

As discussed in the methodology section of this report, study farm A was chosen to represent the smallest one-fourth of cash grain farms reported by the 1974 Census of Agriculture; farm B represents the second one-fourth; and so on. During the linear programming optimization process, some of the study farms (usually the largest) added land to more effectively utilize the machinery complements. The final organization of the largest study farms, averaging \$133,000 gross income, is actually larger than 94 percent of all U.S. cash grain farms in 1974 (*35*, Vol. II, Part 8, p. 49). These relationships provide a basis for understanding the relative importance of the study farm sizes analyzed in this report.

Implications and Limitations of Results

The estimated economies-of-size relationships presented in the previous section meet some of the objectives stated in the introduction of this report. In other cases, shortcomings of the conceptual model upon which this economies-of-size study is based pose severe limitations for attainment of the objectives.

Importance of Technical Economies of Size

The first objective of this study was to determine the importance of technical economies of size in major field crop farming regions. The cost curves estimated in this study suggest that technical economies of size exist on field crop farms but that their importance is not great. The estimated LRAC curves decline significantly at first and then are relatively flat over a wide range. Small or medium-size farms in most regions are nearly as efficient as large farms.

Implications for Farm Managers. Small farms were found to be relatively efficient, compared with the largest farms studied. In five of the regions studied, cash cost/gross income ratios are from \$0.09 to \$0.16 higher on the smallest farms, and in two

Table 6—Comparison of most efficient farm size with farm size required to provide 90-percent resource return rates

Region	Minimum $LRAC_1$ per unit	Size of most efficient farm: Gross income	Size of most efficient farm: Crop land	Size of farm to provide 90-percent resource return rate[1]: Gross income	Crop land	Income as percentage of large farm
	Dollar	*\$1,000*	*Acres*	*\$1,000*	*Acres*	*Percent*
Corn Belt	0.476	145	639	60	299	41
Pacific Northwest	.566	156	1,887	54	449	35
Southeast	.606	130	399	55	143	42
Southern Plains	.536	100	1,488	28	399	28
Texas High Plains	.760	175	974	58	395	33
Northern Plains	.483	105	1,476	17	232	16
Mississippi Delta	.816	122	1,237	47	335	39
Average, seven regions	.606	133	1,157	46	322	33

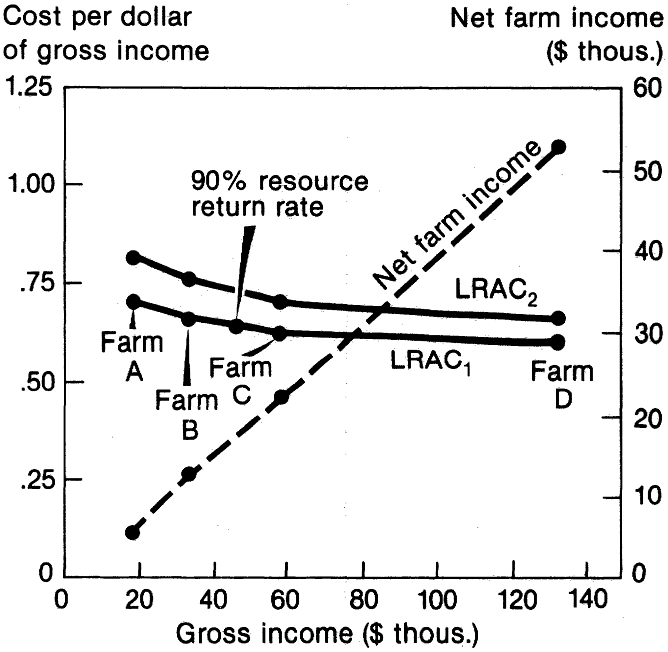
[1]This size has been determined graphically from the LRAC curves in figures 4 to 10. The interpolation along the $LRAC_1$ envelope curve ignores possible discontinuities between the four SRAC curves and assumes that comparable farms exist at all points on the envelope curve.

regions, costs are only $0.04 to $0.05 higher (table 4). Even with the higher costs, returns to land and operator inputs still ranged from $0.14 to $0.47 per dollar income on the smallest farms. Since farms this small are generally part-time units, such cost efficiencies appear sufficient to allow them to continue meeting cash expenses and to return a small but positive net farm income.

The small scale of these farms means that the associated income levels are inadequate to support a family. Nevertheless, they may be viable small business activities from the standpoint of earnings per dollar sales. The persistence of such farms in many areas of the U.S. is better understood by viewing such units as "goods and services firms" (*11*, pp. 21-23). This concept views the farm firm as a producer not only of goods but also of services, such as custom work and off-farm employment, and as having the possibility of hiring various resource services in the amounts needed, as well as owning and operating durable resources. This broader range of economic activities allows the farmer to overcome many of the economic problems of a small farm: custom hiring operations when machine ownership is not justified, performing certain custom services for others when excess machine capacity exists, and using a part-time, off-farm job to utilize operator labor. In this case the farming activity can make an efficient contribution to the total firm as long as its cash costs are lower than its production income and its return to residual claimants is commensurate with their alternative uses in the firm. Such firms often provide an adequate family income and, based on economies of size found in this study, may be nearly as efficient in total as much larger farms.

Figure 11

Average Economies-of-Size Relationships for Seven Field Crop Farming Regions



From a farm planning perspective, the economies-of-size relationships estimated in this study can be helpful to farm managers in making longrun plans in regard to size of farm and the use of land and machinery. The estimated economies of size suggest that medium-size commercial farms with gross incomes from $41,000 to $76,000 achieve most available efficiencies—cash costs on these farms average only $0.024 higher per dollar of gross income than the costs on the most efficient farms with $100,000 to $175,000 gross incomes. For these medium-size commercial farms, the availability of additional technical economies of size appears to be a relatively insignificant consideration in long-term growth planning. It is unlikely that a larger scale operation will significantly improve efficiency in these farms.

The relative flatness of the $LRAC_1$ curves also suggests that net farm incomes are more or less proportional to farm size, a finding that agrees with numerous other studies (*2, 11, 31*). For example on Southern Plains farms,net farm income of $4,300 is obtained on farms with $14,000 sales (a ratio of 31 percent) compared with $46,000 income with $100,000 sales (a ratio of 46 percent). The level of sales is much more important in determining net farm income than are economies of size.

Size Not Only Factor Affecting Efficiency. Other research suggests that economies-of-size studies like the one described in this report are too narrow in their focus, emphasizing size as the primary factor affecting efficiency and ignoring other more important factors that affect efficiency and structural change. Two studies in California have reported a considerable variation of costs *within* farm size groups, and found that, beyond a minimum point, farm size does not explain variation in cost of production (*4, 25*). Similar variations within size groups have been reported by Miller (*15*) and by Goodman (*3*) for wheat farms. Martin has observed that such variation is due to differences in the technologies used, in the rate of technology adaptation, in management ability, and in resource productivity *(12)*. The productivity of fixed factors and the geographic distribution of prices also appear to be more important than size in causing efficiency differences among commercial farms.

Based on this more general view of factors affecting efficiency, farm managers should avoid concluding that size is the primary determinant of efficiency. Past some minimum point when a small machinery complement can be efficiently utilized, factors other than size are much more important in controlling per-unit costs. Concentrating on management and productivity appears to be the most important means of increasing efficiency for commercial farms; size is of much less importance. The best farm managers apparently attain near-maximum cost efficiencies, almost regardless of the size of farm they operate. While size of operation is of primary importance in regard to income, other factors are more important in determining per-unit efficiency.

Economies of Size and Incentives for Growth

A second objective of this study is to investigate the role that economies of size in field crop production plays in structure change—mainly increasing farm size. While moderate technical economies of size have been found to exist on wheat, feed grain, and cotton farms, there is little definitive evidence on whether these economies of size provide a major incentive for farms to grow or whether the lack of diseconomies merely allows farms to grow, with the pressure for growth coming from other sources.

This issue has been considered elsewhere *(15)*. Seckler and Young observe that increasing average farm sizes do not necessarily imply the presence of economies of size—they only imply the absence of significant diseconomies of size *(25)*. They conclude that generalizations which attribute increasing farm size to economies of size or decreasing LRAC will not stand up, and that more empirical studies of intertemporal changes are needed to understand the factors behind changing farm sizes.

Madden supports this view, observing that most farm enlargement occurs in areas and types of farming with minimal management diseconomies (*11*, p. 12). He also describes the weaknesses of the "survivorship technique" which attempts to assess economies of size by assuming that competition among firms will eliminate the more inefficient sizes (*11*, pp. 24-26). Madden questions inferences that small farms are disappearing because they are inefficient.

Boussard argues convincingly that there is an absence of economies of size in agriculture, based on such evidence as a heterogeneous farm size structure *(2)*. He observes that when size economies exist in a certain enterprise, that enterprise breaks away from agriculture and becomes a separate industry, such as the textile industry. He suggests that continued increases in the average farm size are due to the growth in national per capita income and the farm size needed to obtain comparable incomes.

Changing family income needs cannot be overlooked as an incentive for adjustment in agriculture. Net farm incomes on some of the smallest study farms analyzed in this report are at or below the poverty level. Over time, such farmers either expand to increase income, obtain off-farm employment, or exit from farming. In regions where there are few opportunities for off-farm employment, the number of these small farms has decreased substantially in recent years.

The role of income goals in farm growth has received other attention. A Congressional Budget Office report observes that "farmers have a strong incentive to expand the size of their farms in order to increase total profits" (*31*, p. 31). Sparling *(27)* and Seckler *(24)* have also argued that family farms expand to keep up with the Joneses who live in the city—an adaptation of Veblen's "pecuniary emulation" concept.

These studies all challenge the conclusion that small farms do not support families adequately because they are inefficient and that farms grow to become more efficient. An alternative explanation is that small farms generate low net farm incomes, and these low incomes cause such farms to exit, become part-time units, or expand to increase income, whether or not economies of size exist. The relatively limited economies of size found on field crop farms would tend to support this second explanation. The process is accelerated by farm operators seeking to expand landholdings because of the expectation of capital gain, which often exceeds farm income.

Answers to questions about causes of structural change must be based on more comprehensive studies of the process. For example, a recent study by Reimund, and others, takes into account the *dynamics* of firm growth and concentration in agriculture, and better identifies the role played by specific factors, such as economies of size, in the structural change process *(20)*. Their study suggests that the specific nature of technological advance in each sector of agriculture is related to structural change (for example, technological advance in cattle feeding has a much different impact than in feed grain production). Economies of size are sometimes a feature of technological advance, and sometimes not. Their evaluation of technological advance in feed grain production is consistent with the moderate economies of size reported herein. Efficiency-size relationships in feed grain farming may *allow* farm growth and concentration of production, but do not directly *cause* this process.

Economies of Size and the Effect of Farm-Size Limits

The third objective of this report is to explore the possible impacts of farm-size limits on food prices and resource returns, given the economies of size found in field crop farming. The economies of size estimated in this study are quite modest. But even in the presence of substantial economies of size, economists find little agreement on the impact of policies to limit farm size.

Decreased Resource Returns or Increased Food Prices? The 160-acre limit of the Reclamation Act of 1902 is an example of a size limit policy that has received considerable attention. Two different impacts have been hypothesized. Martin argues that if these restrictions are effective, "given that there are economies of size, the marginal cost curves for the average farm, excluding the cost of land, will shift to the left. Thus assuming a constant total demand for food and fiber, total output of food and fiber will decline and prices will rise" *(13)*. Martin's is the more traditional viewpoint: forced reductions in farm size that move farmers to higher points on the LRAC curve will decrease efficiency and result in higher food costs.

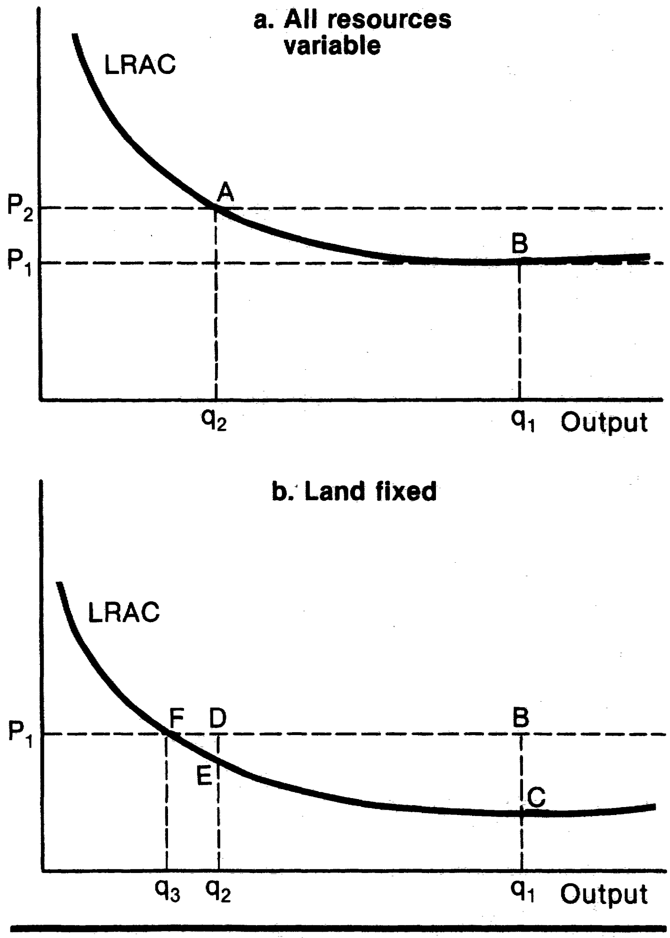
Suggesting an alternative hypothesis, Hall and LeVeen conclude that "the major impact of enforcing the acreage and residency provisions of the Reclamation Act will, therefore, be to reduce the wealth of the current land owner..." *(4)*. They argue that "...food prices will not increase; rather, land values in reclamation projects may decline, causing substantial wealth losses to the current landowners." Assuming that economies of size are present, these researchers appear to disagree over whether farm-size limits would primarily affect food prices or land values.

This disagreement is illustrated in figure 12. Part a shows the effects of a farm size-limit policy under perfect competition with perfect resource mobility. Here, all resources are available to the industry at a constant price—perfectly elastic resource supplies. The LRAC covers all costs and normal profits. In longrun equilibrium, all farms are at a size q_1 corresponding to the low point on the LRAC, point B.

Now consider a farm policy limiting all farms to output q_2. New farms would enter the industry until a new equilibrium is reached with all farms having shortrun average cost curves tangent to the LRAC at

Figure 12.

Effect of Farm Size Limits under Alternative Industry Resource Supply Conditions



this output, point A. However, since the LRAC of these farms is greater than the original average cost, a new price P_2 is necessary for these smaller farms to continue to pay for their resources and continue producing. This price increase would be passed on to consumers. Total production costs are increased and efficiency is decreased by a farm size-limit policy under these conditions.[11]

Alternatively, consider a farm size-limit policy under an assumed fixed land supply as in part b of figure 12. Here land is fixed to the industry, the LRAC covers all costs except land, and land earns an economic rent BC—similar to figure 2 earlier in this report. In equilibrium, farms produce q_1 output. With a size limit policy that limits farms to output q_2, new farms enter the sector until a new equilibrium is reached with all farms at size q_2. Land rents adjust downward from BC to DE at this point, and the equilibrium price is unchanged. Total food production costs are not affected by the farm-size policy even though each farm is operating at a less efficient point on the LRAC curve. The inefficiency is translated into reduced land rents and values, which are borne by landowners.

Food prices will not increase in part b until the size limit is less than q_3, again the extensive margin for land. Limiting farm size to less than q_3 would cause the equilibrium food price to increase.

Economies of size and the slope of LRAC for farms larger than q_3 are irrelevant to society's concern with the price of food. Farm size limits between q_3 and q_1 only affect the relative land value adjustment required to reach a new equilibrium. If economic rents to land are high before the size limit, significant downsizing can occur before food costs are affected. This is apparently the situation that Hall and LeVeen are referring to when they conclude food prices would not be affected *(4)*.

[11]This example represents a policy placing a limit on the output (or gross sales) of individual farms. Farms with a size such that the AC is tangent to the LRAC at point A would be the most efficient allowed under this policy—although their SRAC would be decreasing at A and they would equate MC with P_2 at an output larger than q_2 without the output limit. No other farm size could cover costs at point A and price P_2. A policy limiting one input (like land) on each farm would cause a slightly different longrun equilibrium. Here, farms with the maximum allowable land would equate MC, SRAC, and price and produce at a point above the LRAC curve. Hence, the resulting product price for output q_2 would be slightly higher. These differences are minor and may be ignored for purposes of this argument.

Generalizations for U.S. Field Crop Production. Of course, parts a and b of figure 12 are simplifications of extreme situations. The real world is much more complex. Henderson and Quant describe a situation in agriculture where one category of farms operates on a fixed amount of fertile land and the remaining farms operate under perfect competition (5, p. 99). For many commodity groups, U.S. production takes place in many subregions where the supply of land is fixed (fig. 12b) and in a few subregions which operate at the extensive margin and where the land supply is variable (fig. 12a). Farm size-limit policies would not have an effect on product (food) prices in the numerous subregions where land is fixed, unless farm sizes are reduced until the LRAC with zero land rent is forced above the price (point F in fig. 12b). In the marginal subregions, a size limit policy forces farms to operate at a higher point on the LRAC curve. Since all variable resource costs cannot be covered, some farms go out of production until the decreased supply causes product prices to increase and cover costs on the remaining farms. In the aggregate, due to the buffering impact of production response to these price increases in the more fertile subregions, the product increase would be much less than an industry composed solely of such marginal farms.

Therefore, farm size-limit policies may have different effects on different subsectors of agriculture. The effects on resource returns and food costs depend upon economies of size and the relative importance of the fertile, fixed land subregions compared to the marginal subregions. In certain situations, size limits may increase food prices by increasing longrun production costs. Size policies could also decrease economic rents, depress land prices, and decrease the wealth of the landowners without affecting food prices. The 160-acre limit may have this effect because of the fixed quantity of cropland in irrigation districts.

A combination of food price increases and decreased economic rents for land could result from limiting farm size, with the product price increase accompanied by land abandonment in marginal areas. Even if significant economies of size are present, it is extremely unlikely that moderate farm size limits in a capital intensive agriculture would be translated fully into food price increases; land values would absorb most of the required adjustment. In view of the relative flatness of the $LRAC_1$ relations found in this report, there is little evidence that policies slowing growth or limiting the size of field crop farms would substantially affect either land values or food prices.[12]

Other Factors Related to Efficiency. The more general view of factors other than size affecting efficiency also has implications from the impact of a farm size-limit policy *(25)*. Only the theoretically smooth economies-of-size relationships from economic engineering studies or econometric analyses support the idea that farm size-limit policies cause inefficiency. If efficiency is related to management factors and not to size, a change to smaller farms would cause inefficiency only if land was allocated from superior to inferior managers. Viewing the size-efficiency relationship as a scatter diagram suggests this inefficiency would be unlikely *(25*, page 584).

Thus, a more inclusive perspective of size, efficiency, and resource availability challenges conventional wisdom both in respect to the role economies of size plays in structural change and the efficiency aspects of farm size-limit policies. Research concerning nonsize factors that affect farm efficiency, as well as the dynamic and intertemporal aspects of agricultural change, is required for a detailed understanding of these relationships.

The Remaining Problem

This report has highlighted the problems encountered in imputing costs to fixed production factors and identifying residual claimants in economies-of-size studies. For farm management questions, imputed costs can sometimes be based on individual farmer expectations, and such problems can be diminished. However, in using economies-of-size estimates to understand structural change and for policy analysis, these cost imputation problems are much more complex and may never be completely resolved.

The survivability or persistence of various farm sizes depends upon the minimums that the respective farmers are willing to accept for returns to fixed resources such as land and equity capital, and on either the opportunity cost or the reservation price for operator and family labor. As Madden has argued, with rapid and continuing land appreciation, little can be said about the minimum returns required to keep these resources in agriculture in the long run and the survivability of farms of different sizes (*11*, p. 17).

Many arguments can be made for varying imputed or opportunity costs by size of farm. Raup has argued that large farm businesses (corporate or noncorporate) must impute the full opportunity cost of land capital in their profit calculations, but that family type farms carry this capital at lower rates because of intangible returns from farming (*19*, p. 306). In economies-of-size terms, this argument suggests that equilibrium economic rents to land and operator inputs on small farms may be much lower than on the most efficient size farms, resulting in a leveling out of the otherwise downward sloping LRAC curve in favor of smaller farms.

Logic also suggests that the proper imputed cost for operator and family labor also varies by size of farm. Yet these imputed costs are essentially unobservable and unmeasurable to outside analysists *(18)*. They will continue to pose problems for economies-of-size research.

Even in the case of farm inputs purchased in the marketplace, a problem exists. Holland observes that market prices often do not reflect underlying resource scarcities because of externalities, imperfect competition, and other aberrations from the perfectly competitive model (*6*, pp. 8-11). Thus even in the absence of size economies, society may still gain or lose from creating small farms out of large farms when the social opportunity cost of resource use differs from the opportunity costs used in the analysis. Farm-size limits may also restrict innovation and technological advance, if small farms are less innovative than large farms. In such cases, empirical estimates of LRAC curves may be inaccurate and misleading in real world assessments of various farm-size policies.

Considering these difficulties, policy generalizations based on the results of economies-of-size analyses must be very carefully considered. The assumptions underlying these analyses often provide little defense for such generalizations.

[12]The analysis here is partial, and limited to only two of the possible negative impacts of such policies—higher food costs and reduced asset values. Numerous other cost and benefit factors must be considered in evaluating farm-size policies. Obviously, such policies would reduce incomes of affected farms in proportion to any reduction in size, and be accompanied by resulting adverse impacts on farmers.

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Appendix

Formulation of the Linear Programming Model

The cost minimization linear programming model used in this research is similar to the one reviewed by Madden (*11*, p. 30). Data required for the model include the technical input-output coefficients (a_{ij}), variable costs (c_j), average gross revenue for all real activities (r_j), and the resource constraint levels (b_i). The problem is one of determining x_j such that:

$$\sum_{j=1}^{n} c_j x_j = \text{minimum}$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j \leqslant b_i,$$

$$\sum_{j=1}^{n} x_j r_j = R, \text{ a specified level of gross income, and}$$

$$x_j \geqslant 0 \text{ for all } j.$$

It determines the least cost mix of enterprise (x_j) to produce specified levels of output (measured in R, gross income); the average cost associated with each level of output forms the estimated SRAC curve. The main fixed resources for the farm in the short run (b_i) were the time restraints associated with the specified machinery complement.

Description of the Study Farms

Appendix table 1—Corn Belt: Farm-size interval data and initial study-farm sizes

Item	Unit	Farm A	Interval Bound	Farm B	Interval Bound	Farm C	Interval Bound	Farm D
Size interval data:								
Ag. census, 1974[1]—								
Percentile	Pct.	21	30	43	55	66	77	83
Cropland harvested	Acre	—	90	—	180	—	320	—
Av. cropland harv.	Do.	—	—	—	—	225	—	—
Percent in interval	Pct.	30	—	25	—	22	—	23
FEDS Survey, 1978[2]—								
Total cropland	Acre	—	90	—	180	—	320	—
Surveys in interval	No.	53	—	76	—	129	—	322
Percent in interval	Pct.	9.1	—	13.1	—	22.3	—	55.6
Initial study farm size:								
Farmland	Acre	68	—	137	—	253	—	400
Total cropland	Do.	65	—	130	—	240	—	380
Cropland harvested	Do.	65	—	130	—	240	—	380

— = Not applicable.
[1]All cash grain farms in Illinois, Iowa, Indiana, and Missouri *(35)*.
[2]All questionnaires completed in Illinois, Iowa, Indiana, and Missouri *(32)*.

Appendix table 2—Pacific Northwest: Farm-size interval data and initial study-farm sizes

Item	Unit	Farm A	Interval Bound	Farm B	Interval Bound	Farm C	Interval Bound	Farm D
Size interval data:								
Ag. census, 1974[1]—								
Percentile	Pct.	24	30	44	55	66	79	87
Cropland harvested	Acre	—	122	—	334	—	730	—
Av. cropland harv.	Do.	—	—	—	—	485	—	—
Percent in interval	Pct.	30	—	55	—	24	—	21
FEDS Survey, 1978[2]—								
Total cropland	Acre	—	160	—	440	—	960	—
Surveys in interval	No.	12	—	57	—	109	—	282
Percent in interval	Pct.	2.5	—	12.5	—	23.8	—	61.3
Initial study farm size:								
Farmland	Acre	125	—	300	—	640	—	1280
Total cropland	Do.	120	—	290	—	630	—	1250
Cropland harvested	Do.	91	—	220	—	480	—	950

— = Not applicable.
[1]All cash grain farms in Washington, Oregon, and Idaho (35).
[2]All questionnaires completed in Washington, Oregon, and Idaho (32).

Appendix table 3—Southeast: Farm-size interval data and initial study-farm sizes

Item	Unit	Farm A	Interval Bound	Farm B	Interval Bound	Farm C	Interval Bound	Farm D
Size interval data:								
Ag. census, 1974[1]—								
Percentile	Pct.	24	32	48	65	72	84	89
Cropland harvested	Acre	—	80	—	210	—	430	—
Av. cropland harv.	Do.	—	—	—	—	238	—	—
Percent in interval	Pct.	32	—	33	—	19	—	16
FEDS Survey, 1978[2]—								
Total cropland	Acre	—	80	—	210	—	430	—
Surveys in interval	No.	18	—	36	—	43	—	136
Percent in interval	Pct.	7.8	—	15.4	—	18.5	—	58.3
Initial study farm size:								
Farmland	Acre	70	—	136	—	270	—	560
Total cropland	Do.	60	—	130	—	260	—	540
Cropland harvested	Do.	60	—	130	—	260	—	540

— = Not applicable.
[1]All SIC class (0133, 0134, 0139) field crop farms in Georgia. These farms have more cropland than other classes (35).
[2]All questionnaires completed in Georgia and Alabama (32).

Appendix table 4—Southern Plains: Farm-size interval data and initial study-farm sizes

Item	Unit	Farm A	Interval Bound	Farm B	Interval Bound	Farm C	Interval Bound	Farm D
Size interval data:								
Ag. census, 1974[1]—								
Percentile	Pct.	34	38	53	62	68	82	88
Cropland harvested	Acre	—	180	—	320	—	520	—
Av. cropland harv.	Do.	—	—	—	—	339	—	
Percent in interval	Pct.	38	—	28	—	21	—	22
FEDS Survey, 1978[2]—								
Total cropland	Acre	—	180	—	320	—	520	—
Surveys in interval	No.	92	—	117	—	158	—	631
Percent in interval	Pct.	9.6	—	12.2	—	16.5	—	65.7
Initial study farm size:								
Farmland	Acre	225	—	360	—	500	—	820
Total cropland	Do.	160	—	260	—	360	—	610
Cropland harvested	Do.	160	—	260	—	360	—	610

— = Not applicable.
[1]All cotton and cash grain farms in Kansas, Colorado, Nebraska, and Oklahoma *(35)*.
[2]All questionnaires completed in Kansas, Colorado, Nebraska, and Oklahoma *(32)*.

Appendix table 5—Texas High Plains: Farm-size interval data and initial study-farm sizes

Item	Unit	Farm A	Interval Bound	Farm B	Interval Bound	Farm C	Interval Bound	Farm D
Size interval data:								
Ag. census, 1974[1]—								
Percentile	Pct.	22	35	48	64	72	83	89
Cropland harvested	Acre	—	150	—	360	—	640	—
Av. cropland harv.	Do.	—	—	—	—	379	—	—
Percent in interval	Pct.	35	—	29	—	19	—	17
FEDS Survey, 1978[2]—								
Total cropland	Acre	—	150	—	360	—	640	—
Surveys in interval	No.	16	—	30	—	53	—	127
Percent in interval	Pct.	7.1	—	13.3	—	23.5	—	56.2
Initial study farm size:								
Farmland	Acre	103	—	240	—	462	—	835
Total cropland	Do.	94	—	230	—	450	—	820
Cropland harvested	Do.	94	—	230	—	450	—	820

— = Not applicable.
[1]All cotton and grain farms in the State *(35)*.
[2]All questionnaires completed in three Northwest Texas areas *(32)*.

Appendix table 6—Northern Plains: Farm-size interval data and initial study-farm sizes

Item	Unit	Farm A	Interval Bound	Farm B	Interval Bound	Farm C	Interval Bound	Farm D
Size interval data:								
Ag. census, 1974[1]—								
Percentile	Pct.	22	28	42	56	66	77	84
Cropland harvested	Acre	—	240	—	445	—	685	—
Av. cropland harv.	Do.	—	—	—	—	—	—	—
Percent in interval	Pct.	28	—	28	—	21	—	23
FEDS Survey, 1978[2]—								
Total cropland	Acre	—	280	—	520	—	800	—
Surveys in interval	No.	27	—	82	—	101	—	439
Percent in interval	Pct.	4.2	—	12.6	—	15.5	—	67.7
Initial study farm size:								
Farmland	Acre	246	—	418	—	664	—	990
Total cropland	Do.	234	—	397	—	630	—	940
Cropland harvested	Do.	200	—	340	—	540	—	805

— = Not applicable.
[1]All cash grain farms in Montana, North Dakota, and South Dakota *(35)*.
[2]All questionnaires completed in Montana, North Dakota, and South Dakota *(32)*.

Appendix table 7—Mississippi Delta: Farm-size interval data and initial study-farm sizes

Item	Unit	Farm A	Interval Bound	Farm B	Interval Bound	Farm C	Interval Bound	Farm D
Size interval data:								
Ag. census, 1974[1]—								
Percentile	Pct.	24	31	48	65	72	85	89
Cropland harvested	Acre	—	80	—	320	—	720	—
Av. cropland harv.	Do.	—	—	—	—	374	—	—
Percent in interval	Pct.	31	—	34	—	20	—	15
FEDS Survey, 1978[2]—								
Total cropland	Acre	—	80	—	320	—	720	—
Surveys in interval	No.	12	—	50	—	76	—	258
Percent in interval	Pct.	3.0	—	12.7	—	19.2	—	65.1
Initial study farm size:								
Farmland	Acre	68	—	170	—	430	—	920
Total cropland	Do.	60	—	160	—	420	—	900
Cropland harvested	Do.	60	—	160	—	420	—	900

— = Not applicable.
[1]All cash grain farms in Arkansas, Mississippi, and Louisiana *(35)*.
[2]All questionnaires completed in Arkansas, Mississippi, and Louisiana *(32)*.

Resource, Cropping, and Management Practices

This section of the appendix contains a detailed description of the resources and practices identified for the study farms in each region.

Labor Assumptions. Labor availability was defined for 13 periods during the year, generally beginning in March and ending in November. Appendix table 8 shows the hours of operator labor available for each of the time periods. There were six 1-week labor periods for the critical land preparation and planting activities beginning in the month of March or April, depending upon the region. Five 2-week periods covered the harvest season beginning in September. The remainder of the cropping season was divided into two periods, one of which was 3 weeks long. The constraint for each period was developed according to the number of rain-free days suitable for fieldwork.

The basic labor constraint for all farms was the time available to the farm operator. Additional labor could be hired when required for selected labor-intensive operations, or on larger farms depending upon needs for additional tractor or machine operators. Labor hiring was generally restricted to the number of workers that could be utilized by the machinery complement.

Tractor Hour and Machinery Time Assumptions. Machinery complements were defined for each study farm in each region based on the 1978 cost of production survey *(32)*. The number of tractors and implements on each farm, and the size and capacity of each item in the machinery complement were assumed to be the same as found on similar farms in the 1978 survey. The resulting machinery complements were the primary fixed factors used in determining the SRAC curves on the study farms.

In the model, the labor period became the basis for all subsequent machinery time constraints since these were also based on the "rain-free days" concept. Tractor time was constrained for 10 of the most critical periods. Machinery time constraints were defined for spring and fall land preparation, spring and fall planting and postplanting operations, and for harvesting operations. Depending upon the machinery complement and labor available for the farm, any and all of these operations could occur during the same time period.[13]

Enterprise Budgets. All of the technical coefficients in the enterprise were developed using data from the FEDS 1978 cost of production survey *(32)*. The FEDS budget generator was used to construct these enterprise budgets for each study farm in each region using the machinery complements. The technical coefficients for the linear programming matrix were taken from the enterprise budgets.

Coefficients were developed for all land preparation, planting, postplanting, and harvesting operations. Labor and tractor requirements were developed from the machinery requirements data. All of the technical coefficients were developed according to the calendar of operations specified by the cultural practices for each farm enterprise. The cost data used in the linear programming objective function were likewise taken from the enterprise budgets.

Gross income coefficients for all crop enterprises were developed using the historical yields from the FEDS budgets projected to 1980 on the basis of the FEDS crop enterprise budgets and State longrun yield trends. The prices received for these crops also came from FEDS budgets. These yields and prices received are shown in appendix table 9.

Activities. For each type of farm, the crop activities were those included in the FEDS typical farm series *(28)*. Crop activities were divided into land preparation, planting and postplanting operations, and harvesting. These operations were separated to take advantage of the alternatives available to farmers. For example, in the Corn Belt, land prepared in the fall is available for planting during any of several planting periods the following spring. The harvesting activities were also developed separately since a crop planted during May can be harvested during different harvesting periods. In all regions the activities corresponded as nearly as possible to actual farming practices.

Limits were placed on some activity combinations. The use of various cropping practices like summer fallow and crop rotations was determined by the linear programming model, but within agronomic restraints applicable to the region. Cropping practices were also restricted when necessary to maintain consistency with projected yields. Cultural practice and type-of-farm constraints were used to assure a given level of income from the principal

[13]A critical data element for estimating economies of size is the field capacity of different sizes of implements and tractors. This study used engineering data on field capacity from the FEDS budget generator. Unfortunately, machine capacity data is one of the weak links in the USDA cost of production estimates. It presents additional difficulties for economies-of-size research because varying cropland acreages and questions about contiguous or distant tracts affect travel time and field capacity. Further research is needed on this topic, both for cost of production and economies-of-size estimates.

Appendix table 8—Hours of operator labor available in each region by labor period

Labor time period	Corn Belt	Pacific Northwest	Northern Plains	Southern Plains	Mississippi Delta	Texas High Plains	Southeast
				Hours			
1	50	40	50	50	50	60	40
2	40	50	50	40	40	50	50
3	40	50	50	50	50	60	50
4	40	60	40	40	40	50	50
5	50	60	40	40	40	60	50
6	40	60	50	50	40	50	50
7	168	216	144	130	216	140	156
8	576	288	504	500	816	800	744
9	100	110	100	100	100	110	100
10	100	90	90	100	100	110	100
11	100	80	80	100	100	110	100
12	64	72	64	64	64	88	64
13	202	243	192	479	212	268	212

Appendix table 9—1980 projected yields and prices for crop enterprises

Region	Yield per acre	Price per bushel	Region	Yield per acre	Price per bushel
	Bushel	*Dollars*		*Bushel*	*Dollars*
Pacific Northwest:			Texas High Plains:		
Winter wheat/continuous	53.14	3.40	Grain sorghum/irrigated	80.57	2.16
Winter wheat/fallow	52.36	3.40	Grain sorghum/dryland	24.10	2.16
Barley/continuous	57.64	1.80	Upland cotton		
Barley/fallow	56.71	1.80	Lint/dryland[1]	259.01	.550
			Seed/dryland[1]	350.74	.055
Corn Belt:			Lint/irrigated[1]	387.39	.550
Winter wheat	36.46	3.05	Seed/irrigated	475.44	.055
Corn for grain	115.10	2.10			
Soybeans	36.46	6.65	Northern Plains:		
Oats	50.37	1.25	Durum wheat/continuous	22.37	2.85
			Durum wheat/fallow	28.44	2.85
Mississippi Delta:			Spring wheat/continuous	21.05	2.70
Winter wheat	28.12	2.95	Spring wheat/fallow	27.45	2.70
Soybeans	21.09	6.70	Barley/continuous	36.38	2.75
Cotton/lint[1]	470.52	.602	Barley/fallow	40.06	1.75
Cotton/seed[1]	761.53	.062			
			Southeast:		
Southern Plains:			Corn for grain	59.50	2.25
Winter wheat/continuous	26.78	2.85	Soybeans	24.21	6.70
Winter wheat/fallow	31.83	2.85	Peanuts[1]	3577.6	.21
Grain sorghum	38.57	1.93	Upland cotton/lint[1]	499.9	.605
			Upland cotton/seed[1]	768.4	.053

[1]Units in pounds.

enterprise for a given type of farm and to limit high value crops to the long-term production capability of the region.

Hiring and renting-in activities were developed for labor, land, and custom work in accordance with viewing the study farms as "goods and services" firms (*11*, pp. 21-23). Custom harvesting of crops could be used when it was more cost efficient than machine ownership. These custom harvest activities were used primarily on the small farms but could be implemented on other farm sizes whenever such activities were more efficient. Custom work was limited in each region to those operations where custom services were found available in the 1978 FEDS Survey.

Machinery Fixed Costs. The operating and fixed costs associated with the study farms are shown in table 3 and appendix tables 10 through 15. The level of these machinery costs on the different farm sizes depends primarily on the age of the machinery and the proportion purchased as used machinery. Other studies have found that small farms control machinery costs by keeping machinery longer and purchasing used rather than new equipment. For example, in Colorado, small wheat farms purchased 71 percent of their equipment used and had machinery complements with an average age of 10 to 14 years, compared with 38 percent used and a 5- to 10-year average age on large farms (*26*, pp. 20-22). Such practices result in a substantial reduction in fixed machinery costs, although some of this saving is offset by increased repair costs on older machines.

The 1978 FEDS Survey only collected used-purchase and average-age data for tractors. The FEDS machinery complements contain data on initial list prices and the average annual use of all machines. The machinery costs used for estimating economies of size in this report were based on these data, assuming that:

- The amount of all machinery purchased used and its average age varies by size of farm according to the age and percentage of tractors purchased used from the 1978 FEDS Survey.
- For all used equipment, the age when purchased used is equivalent to 3 years at the annual use rate shown in the FEDS machinery complements for the various regions.
- The purchase price of the used equipment is a function of the initial list price, the percentage of tractors purchased used, and the average age of tractors.

The average age and percentage of tractors purchased used was obtained from the data on the 1978 FEDS Survey. No information was collected on other implements so the purchase history for tractors was used as a proxy for all machinery. This assumption is consistent with an earlier study done in eastern Colorado which found that the age and purchase strategy of most other machinery corresponded closely to that of tractors (*26*, p. 22).

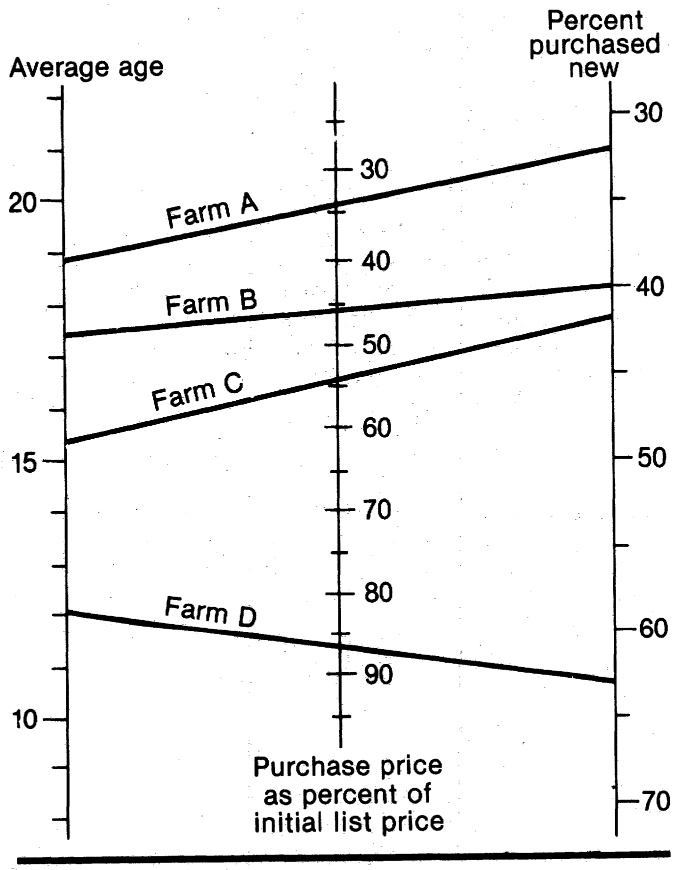
Used equipment is assumed to have been first purchased new on a farm that utilized the equipment at a rate approximating the optimum level represented by the annual-use hours shown in the FEDS regional machinery complements. Three years are assumed at this rate because the eastern Colorado study shows an age difference between new and used machinery varied from 2.2 years for trucks to 4.6 years for rodweeders (*26*, p. 22).

Purchases of used machinery and using it over a longer period of time lowers fixed costs by decreasing the purchase price paid by the farmers and allowing this price to be depreciated over a longer period. Purchase prices for each machine on each study farm were estimated by the use of the nomograph in figure 13, which relates the purchase price of a machine to its initial list price and the average age and percent of tractors purchased new on the study farm. The examples shown in figure 13 are for the Northern Plains. For the small farm, connecting the average survey age of tractors, 18.8 years, with the percent purchased new, 32 percent, yields a purchase price that is 34 percent of the initial list price. Similar purchase prices for the three larger farms are 46, 54, and 87 percent of initial list price, respectively.

Once the percentage of initial list price was determined from figure 13, that percentage was used to determine the purchase price for all implements in the machinery complement of that study farm. The fixed cost of machinery—depreciation, taxes, and insurance—are then computed using these purchase prices and the FEDS budget generator. This procedure had the effect of substantially lowering the fixed costs of machinery on the small study farms in some regions, as suggested by the FEDS Survey data on the age and number of used tractors. Even though machinery repair rates were increased by the use of older used machinery, the net effect was to lower total machinery costs on small farms.

Figure 13

Nomograph Estimating Machinery Purchase Price as Percent of Initial List Price, Based on FEDS Average Age and Percent Purchased New—Northern Plains



Appendix table 10—Corn Belt: Cash operating costs and gross income on study farms

Item	Farm A	Farm B	Farm C	Farm D
	Dollars			
Land rent	456	277	0	0
Hired labor	0	0	0	375
Seed	673	1,387	2,575	6,339
Fertilizer and chemicals	2,308	4,636	9,669	21,221
Custom operations	502	804	0	0
Machinery repair and maintenance	411	637	1,387	3,109
Machinery fuel and lubrication	348	657	1,583	3,313
Interest on operating costs	169	323	668	1,476
Total cash operating costs	4,867	8,721	15,882	35,833
Machinery replacement costs	3,166	6,352	7,304	19,831
Taxes on machinery	196	341	407	1,022
Machinery insurance	118	276	244	671
Total cash machinery costs	3,480	6,969	7,955	21,524
Real estate taxes	743	1,552	2,875	7,105
General farm overhead	509	1,008	1,777	4,583
Total other fixed costs	1,252	2,560	4,652	11,688
Total cash costs	9,599	18,250	28,489	69,045
Gross income	16,000	32,000	53,000	145,000

Appendix table 11—Northern Plains: Cash operating costs and gross income on study farms

Item	Farm A	Farm B	Farm C	Farm D
	Dollars			
Land rent	428	218	898	0
Hired labor	0	0	0	2,430
Seed	492	836	1,647	3,384
Fertilizer and chemicals	684	1,540	3,117	7,050
Machinery repair and maintenance	1,076	1,534	2,706	2,586
Machinery fuel and lubrication	637	801	1,421	4,038
Interest on operating costs	68	134	232	323
Total cash operating costs	3,385	5,063	10,021	19,811
Machinery replacement costs	3,438	5,738	7,732	17,813
Taxes on machinery	236	400	636	901
Machinery insurance	133	219	311	541
Total cash machinery costs	3,807	6,357	8,679	19,255
Real estate taxes	407	727	1,155	2,602
General farm overhead	1,424	2,469	4,015	9,060
Total other fixed costs	1,831	3,196	5,170	11,662
Total cash costs	9,023	14,616	23,870	50,728
Gross income	17,000	28,000	47,000	105,000

Appendix table 12—Southern Plains: Cash operating costs and gross income on study farms

Item	Farm A	Farm B	Farm C	Farm D
	Dollars			
Land rent	0	0	232	0
Seed	356	623	1,039	2,537
Fertilizer and chemicals	1,746	2,968	4,477	10,698
Custom operations	2,019	0	0	0
Machinery repair and maintenance	638	1,759	1,905	3,413
Machinery fuel and lubrication	734	1,466	955	3,551
Interest on operating costs	195	316	422	1,104
Total cash operating costs	5,688	7,132	9,030	21,303
Machinery replacement costs	1,860	3,979	7,435	16,885
Taxes on machinery	121	254	459	936
Machinery insurance	72	153	276	562
Total cash machinery costs	2,053	4,386	8,170	18,383
Real estate taxes	583	971	1,590	3,972
General farm overhead	1,386	2,323	4,026	9,870
Total other fixed costs	1,969	3,294	5,616	13,842
Total cash costs	9,710	14,812	22,816	53,528
Gross income	14,000	25,000	41,000	99,956

Appendix table 13—Mississippi Delta: Cash operating costs and gross income on study farms

Item	Farm A	Farm B	Farm C	Farm D
	Dollars			
Land rent	2,768	760	0	0
Hired labor	0	0	0	2,268
Seed	559	1,018	3,934	5,884
Fertilizer and chemicals	3,047	7,532	13,283	25,313
Custom operations	3,270	1,777	966	0
Machinery repair and maintenance	1,267	2,570	4,062	10,032
Machinery fuel and lubrication	688	1,577	2,659	7,425
Interest on operating costs	201	434	947	1,662
Total cash operating costs	11,800	15,668	25,851	52,584
Machinery replacement costs	6,487	8,743	12,789	31,786
Taxes on machinery	419	610	635	1,256
Machinery insurance	251	327	381	754
Total cash machinery costs	7,157	9,680	13,805	33,796
Real estate taxes	127	273	756	2,243
General farm overhead	760	1,341	3,639	10,908
Total other fixed costs	887	1,614	4,395	13,151
Total cash costs	19,844	26,962	44,051	99,531
Gross income	23,000	32,000	53,000	122,000

Appendix table 14—Texas High Plains: Cash operating costs and gross income on study farms

Item	Farm A	Farm B	Farm C	Farm D
	Dollars			
Land rent	90	1,673	810	0
Hired labor	0	403	927	5,724
Seed	609	1,406	2,031	5,646
Fertilizer and chemicals	1,751	3,977	6,624	14,400
Custom operations	3,465	5,135	6,607	18,900
Machinery repair and maintenance	792	3,073	5,026	11,204
Machinery fuel and lubrication	1,409	3,357	4,478	12,954
Interest on operating costs	298	660	860	2,436
Total cash operating costs	8,414	19,684	27,363	71,264
Machinery replacement costs	6,122	12,568	20,596	49,167
Taxes on machinery	338	647	935	2,194
Machinery insurance	202	388	561	1,316
Total cash machinery costs	6,662	13,603	22,092	52,677
Real estate taxes	171	400	690	1,383
General farm overhead	927	2,270	3,991	7,772
Total other fixed costs	1,098	2,670	4,681	9,155
Total cash costs	16,174	35,957	54,136	133,096
Gross income	19,000	45,000	70,000	175,000

Appendix table 15—Southeast: Cash operating costs and gross income on study farms

Item	Farm A	Farm B	Farm C	Farm D
	Dollars			
Land rent	191	0	0	0
Hired labor	0	0	0	126
Seed	1,259	2,783	4,732	11,831
Fertilizer and chemicals	4,657	10,748	16,200	31,071
Custom operations	196	544	181	0
Machinery repair and maintenance	463	1,624	3,193	4,145
Machinery fuel and lubrication	567	1,311	2,616	4,377
Interest on operating costs	330	724	1,117	2,173
Total cash operating costs	7,663	17,734	28,039	53,723
Machinery replacement costs	4,877	8,417	12,225	18,492
Taxes on machinery	625	509	604	856
Machinery insurance	188	306	362	514
Total cash machinery costs	5,690	9,232	13,191	19,862
Real estate taxes	205	398	800	1,216
General farm overhead	603	1,287	1,582	3,957
Total other fixed costs	808	1,685	2,382	5,173
Total cash costs	14,161	28,651	43,612	78,758
Gross income	20,000	43,000	70,000	130,000

*U.S. GOVERNMENT PRINTING OFFICE: 1981-0-340-932/ESS-129